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CONTENTS

INTRODUCTION

Because of the long distance which Florida strawberries are usually shipped their satisfactory marketing necessitates particular attention to handling and shipping practices. The importance of precooling and transit refrigeration is also generally recognized. These investigations were undertaken to ascertain the most satisfactory and economical methods of handling, precooling, and shipping the harvested berries in commercial carlots.

During the 6-year period ended December 31, 1934, the commercial strawberry crop [2] of the United States ranked sixth in size among the fruit crops of the country, as shown in table 1.

[1] J. R. Winston, C. O. Bratley, J. S. Wiant, T. M. Whiteman, C. L. Powell, and M. J. Payne, of the Division of Fruit and Vegetable Crops and Diseases, and W. V. Hukill, of the Bureau of Agricultural Engineering, assisted in these investigations. Acknowledgment is made of the cooperation and assistance of the various shippers at Plant City and Lawtey, Fla., and of the Railway Express Agency and various railroad companies, which made these tests possible, and of the assistance of A. N. Brooks, of the Florida Agricultural Experiment Station, during the collection and preparation of fruit for the handling tests.

[2] By commercial crop is meant that portion of the total crop which is sold for consumption as fresh fruit.

64678°—36——1

TABLE 1.—*Carlot shipments of fruit crops for the 6-year period ended Dec. 31, 1934*

Fruit crop	Carlot shipments in calendar year indicated					
	1929	1930	1931	1932	1933	1934
Apples	104, 771	107, 033	98, 330	83, 949	65, 244	64, 757
Oranges	97, 959	64, 118	92, 740	81, 320	83, 405	85, 182
Grapes	66, 136	70, 890	46, 971	46, 215	32, 058	32, 610
Peaches	35, 451	38, 490	46, 070	20, 751	28, 263	26, 586
Pears	20, 750	28, 733	20, 419	17, 891	14, 052	17, 343
Strawberries	18, 732	10, 578	13, 770	12, 931	13, 212	12, 033

The strawberries were shipped from more than 30 States, but in greatest volume from Alabama, Arkansas, Florida, Louisiana, Maryland, Missouri, North Carolina, Tennessee, and Virginia. The early crop came from Alabama, Florida, Louisiana, Mississippi, and Texas, but the first three States furnished, on the average, about 96 percent of the shipments.

Table 2 shows that the volume of strawberry shipments from the five Southern States that produce the bulk of the early crop has been above 3,000 cars each year during the 7-year period ended December 31, 1935, with a peak of about 8,000 cars in 1931. This trend toward heavier production indicates that the value of strawberries as a cash crop is being realized in those States, and consequently that the importance of marketing them to the best advantage should be recognized by growers, shippers, and carriers. The marked reduction in the commercial crop of 1935 in these five States was due chiefly to unfavorable weather conditions in Louisiana and Florida during the production of the crop.

TABLE 2.—*Carlot shipments of strawberries from certain Southern States for the 7-year period ended Dec. 31, 1935*

State	Carlot shipments in calendar year indicated						
	1929	1930	1931	1932	1933	1934	1935
Alabama	1, 354	771	1, 154	755	893	450	363
Florida	1, 739	1, 630	1, 992	1, 685	2, 043	1, 803	1, 368
Louisiana	2, 859	2, 389	4, 720	2, 664	2, 610	2, 778	1, 826
Mississippi	115	74	127	131	114	73	50
Texas	253	92	65	38	41	105	13
Total	6, 320	4, 956	8, 058	5, 273	5, 701	5, 209	3, 620

Prior to 1929 most of the Florida strawberry crop was shipped to market in heavy double-walled wooden cases known as pony refrigerators (figs. 1 and 2). These have a capacity of 32, 64, or 80 quarts and, as the name implies, are so constructed that ice can be supplied for refrigerating the fruit while in transit. In 1929 new tariffs established by the transportation companies made it possible to ship strawberries out of Florida more economically in crates in carload lots. Since that time pony refrigerators have been used for the handling of a relatively small volume of less-than-carlot shipments and most of the crop moves to northern markets in refrigerator cars. The shipment of strawberries by truck is practiced to some extent in Florida

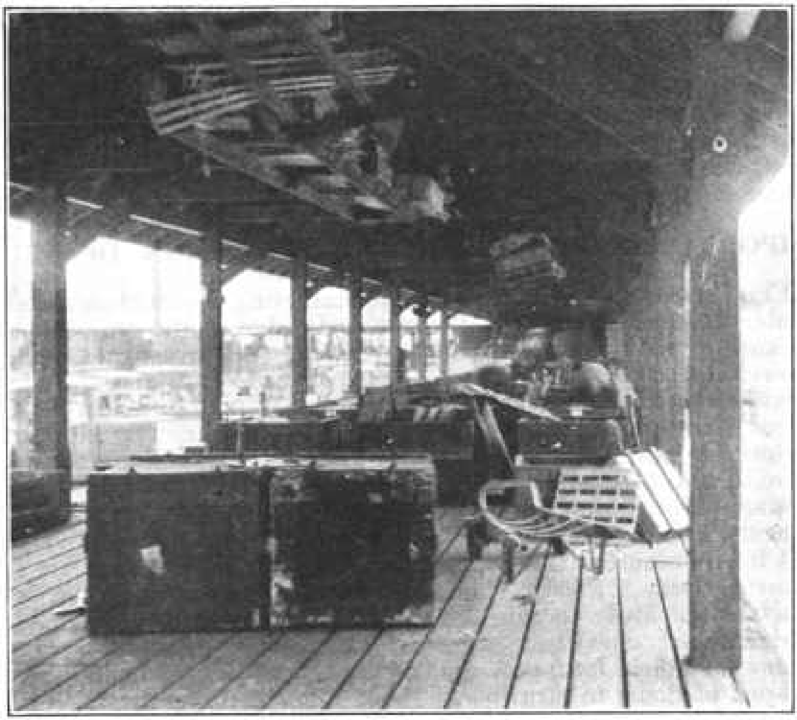

FIGURE 1.—Pony refrigerators on the loading platform, Plant City, Fla.

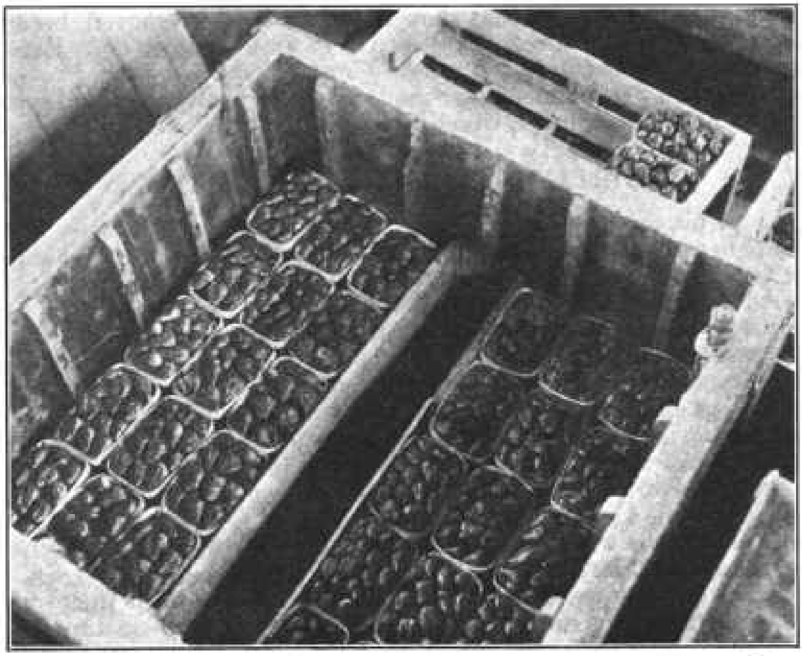

FIGURE 2.—Pony refrigerator partly filled with pint cups of berries. A horizontal ice pan is placed above the top layer of cups, resting on side cleats and the perpendicular metal structure at center.

but is much less important there than in North Carolina and the Chesapeake Peninsula (Delaware and part of Maryland and Virginia). During recent years the tonnage of strawberries hauled in trucks from the two latter districts has far exceeded that hauled in refrigerator cars. A brief discussion of the investigations conducted by the United States Department of Agriculture, on the transportation of strawberries by truck and of some of the results obtained will be found on page 52.

IMPORTANCE OF QUALITY AND CONDITION OF FRUIT

Close attention to all phases of the marketing of strawberries is desirable not only because of the size and value of the crop but also because of its perishability. Observations and investigations have shown that under the usual storage or transit conditions the life of strawberries as a marketable commodity varies from a few days to about 2 weeks. In most instances, this fruit cannot be held satisfactorily in a fresh state, even under the best of conditions, for much more than a week, after which time there is danger of loss from decay, wilting, and deterioration in color.

Fruit that is well colored but firm will hold up better than overripe, soft fruit, because it is less likely to be damaged by bruising and subsequent decay. Poorly colored, green fruit usually carries well, but it is not likely to gain much in red color while in transit under refrigeration. Strawberries picked while partly green do color up somewhat if held for 2 or 3 days at the temperatures usually prevailing out of doors in strawberry time. This fact, however, is of no practical importance in the handling of the fruit by rail under refrigeration.

In grading, all berries that show decay should be removed, because they are almost certain to be a source of trouble later on. Even a small percentage of decay in a load may develop and spread to such an extent as to cost the shipper many times the value of the insignificant number of berries in which it originally occurred.

IMPORTANCE OF FRUIT TEMPERATURE

High fruit temperatures at the time of loading are extremely undesirable because they make it difficult to cool the load to a good carrying temperature. Consequently strawberries should be picked and loaded as early in the day as possible in order to avoid the high air temperatures of midday or afternoon. A common practice in Florida is to wash the fruit before packing so as to remove sand and soil. This practice also helps to cool the fruit considerably, especially if ice is kept in the wash water. This water should be changed frequently (at least twice a day) to avoid as much as possible the contamination of the fruit with spores of decay fungi, which undoubtedly occurs when dirty water is used. After being graded and packed the fruit should be kept in the shade until hauled to the car for loading, and while on the way to the loading point it should be protected from the sun as much as possible to avoid further warming up.

High fruit temperatures in transit (above 50° F.) favor the growth of rot fungi and the development of decay. At a temperature of 50° the development of "leak", one of the most common diseases of strawberries in transit (*10, 13*)[3] (caused by the fungus *Rhizopus nigricans*), is held in check for about 3 days; below 45° it is practically negligible for 6 days or more (*2, 12*). The fungus known as gray mold (*Botrytis*) also attacks strawberries and is able to develop at temperatures considerably lower than those that check *Rhizopus*.

Studies of the behavior of gray mold on apples by Brooks and Cooley (*1*) and on Globe artichokes by Link, Ramsey, and Bailey (*6*) show that a temperature of 41° F. will keep it from spreading from diseased to healthy material, but that a temperature of 32° or slightly lower is necessary to stop its growth in tissues where it is already established. These facts are additional reasons for careful grading of strawberries to remove all diseased fruits. In many instances both gray mold and *Rhizopus* enter the fruit at bruises or cuts, hence it is highly important that the fruit be handled carefully at the time of harvest and during grading, packing, loading, and unloading. Gray mold also spreads from diseased berries to sound, healthy ones that touch them, forming clumps or nests of decay similar to those in packages of pears attacked by gray mold. In such cases the fungus is able to penetrate the uninjured skin of the sound fruit, and infection is described as having taken place by contact.

Leather rot (*9*) has not been found in Florida strawberries but is sometimes very destructive in the field in Arkansas and Tennessee and in fruit shipped from those States. It is also known to occur in Louisiana and other Southern States. The rot is able to develop so rapidly at temperatures of 40° to 45° F. as to cause heavy loss in 3 to 4 days.

A high full pack is desired by most strawberry buyers, but it may easily result in excessive loss from decay because of bruising and crushing of the berries when the cups are in place in the crate and the lid is closed. It would be much more desirable if buyers would demand that the berries be packed firmly in the cups, flush with the top around the edge and with a "crown" of not more than half an inch at the center. Such a pack would allow for some slackness developing in transit but would avoid the crushing or cutting of berries at the rim of the cup due to pressure of the divider.

The use of crates of a different design from the type now in most common use, which would help to prevent excessive bruising and crushing in transit, is recommended. During the spring of 1934 observations were made on the condition, upon arrival, of strawberries shipped from Willard, N. C., in crates designed at the North Carolina Coastal Plain Branch Experiment Station (fig. 3). In these crates the dividers that separate the layers of cups are supported by cross slats on the frame in such a way that they do not touch the berries in the layer beneath. A sheet of cellophane laid over the cups in each layer keeps the berries from falling out between the slats of the cover or divider. In shipments made in such crates the percentage of bruised berries was found to be very small.

In some parts of the country a patented cup is used in which four "ears", one at each corner, project about half an inch above the veneer binding strip at the top of the cup (fig. 4). In California, strawberries are shipped in lidless crates that will hold only one layer of cups, but with cleats on the under side at the ends to prevent crushing of the fruit when the crates are stacked. No tests were conducted with these

[3] Italic numbers in parentheses refer to Literature Cited, p. 57.

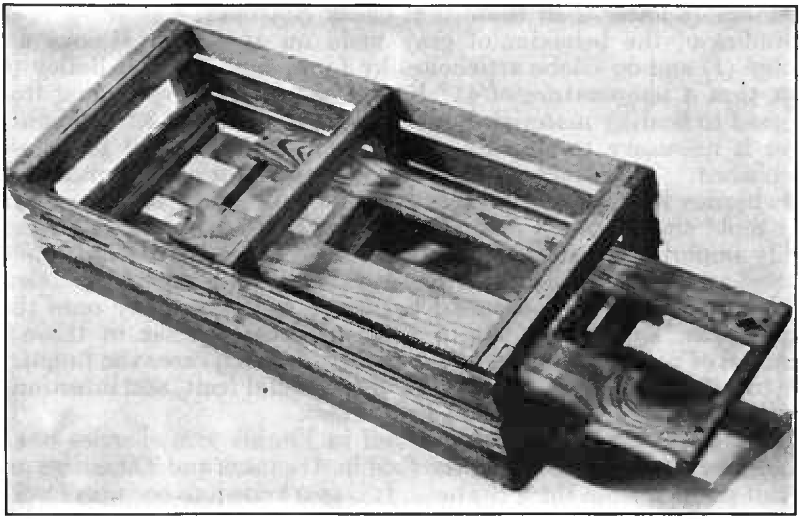

FIGURE 3.—Strawberry crate developed at the North Carolina Coastal Plain Branch Experiment Station in an attempt to prevent bruising of fruit during the process of marketing. The dividers rest on cross pieces at the middle and ends of the crate instead of directly on the berries and the tops of the cups, as in the usual type of crate.

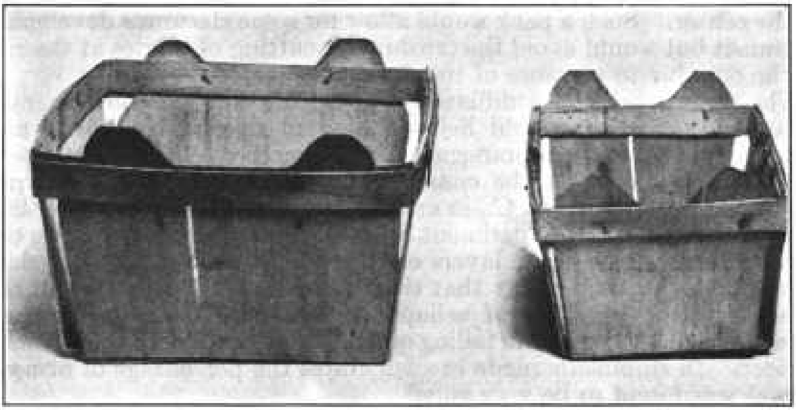

FIGURE 4.—Quart and pint containers for strawberries and other small fruits. The "ears" at the corners are intended to reduce bruising of the fruit.

specially designed cups, or with the California crate, but there can be no doubt that the use of them would mean much less bruising than has heretofore been considered inevitable in strawberry shipments.

INVESTIGATIONS ON HANDLING

In 1931 and 1932 investigations were made in Florida on the handling of strawberries, in order to discover the effects of some of the practices followed by growers in the preparation of this fruit for the market.

EFFECT OF WASHING BERRIES

It is the practice in most strawberry-producing districts in Florida to wash the fruit before it is graded and packed, either by dipping it into water or by subjecting it to a spray. This procedure removes most of the sand and dirt and thus makes the fruit more attractive. Some of the excess water is usually allowed to drain away and frequently enough time elapses before the fruit is loaded so that some actual drying occurs; however, in many instances the washed fruit is at least damp when placed in the cars. Therefore the question arises whether there is any difference in the carrying quality of wet and dry fruit. The problem was investigated by Stevens and Wilcox (*14*, *15*) in 1917 and 1918 who concluded that the practice of washing strawberries "is not necessarily harmful provided the fruit is packed wet, handled with care and placed under refrigeration within a reasonable time." Their results indicated that the keeping quality of the fruit might even be improved by the washing treatment, but that to allow the washed fruit to dry before it was packed had a decidedly injurious effect.

During the transportation investigations in Florida in 1931 (see discussion, p. 50), tests were made to determine the behavior of wet and dry strawberries while en route by express refrigeration from Plant City and Lawtey, Fla., to New York and Philadelphia.

For the first test, made late in March, two crates of berries were obtained, the contents were sorted to remove all bruised or otherwise imperfect fruit, and then distributed into quart cups. Half of these berries were washed and allowed to drain for a few minutes, and then used with dry berries to make up lots for placing in the two test cars. Each lot consisted of 2 quarts of wet and 2 of dry berries, the different lots being placed in crates in the cars on top of the load at the doorway and on the floor racks at the doorway, all of which were on the center line of the car. Inspection at New York showed that in three out of the four lots of test fruit from the two cars, the percentage of sound berries averaged 4 percent greater in the fruit that was loaded while wet than in that loaded while dry. In the fourth lot the percentage of sound fruit was 2.5 percent higher in the fruit that was dry when loaded.

In two similar tests conducted in April it was found on inspection at destination that there was great irregularity in condition among the test lots but, on the average, very little difference in percentage of sound, soft, or decayed berries between the wet and dry lots. The results of these tests are summarized in table 3. Soft berries include those having wet spots on the surface because of bruises or skin breaks.

TABLE 3.—*Percentage of sound, soft, and decayed berries on arrival at Philadelphia or New York, in test lots of fruit packed wet or dry at shipping point, Lawtey, Fla., 1931*

Test no. and car	Sound		Soft [1]		Decayed	
	Wet	Dry	Wet	Dry	Wet	Dry
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1931-3:						
A	63.0	58.8	36.8	40.9	0.2	0.3
B	63.5	57.3	36.5	42.7	.0	.0
C	60.3	65.6	39.7	34.2	.0	.2
Average	62.2	60.6	37.7	39.2	.06	.16
1931-4:						
A	84.5	90.7	15.1	8.5	.4	.8
B	87.4	82.4	12.2	17.2	.4	.4
C	77.3	80.8	22.5	19.2	.2	.0
Average	83.4	84.6	16.6	14.9	.3	.4

[1] Mashed or bruised, skin broken, and injured areas wet.

Further investigations were made in 1932 to determine how the washing of strawberries affects their carrying quality. Three shipping tests were made, each in a different car, two of which went to New York and one to Philadelphia. The test crates in the latter were removed from the car and shipped to New York by open express without refrigeration. The methods by which the berries were prepared for the tests were as follows:

Test no. 1.—The berries used were bought from two growers. After they were delivered at the packing shed they were sorted as previously described (p. 7) and distributed into two lots of 11 pints each, so that each cup contained equal quantities of fruit from the two growers. One of these lots was washed in clean water; the other was not washed.

Test no. 2.—The fruit used was bought from one grower and was rather dirty. It was divided into two lots of 12 pints each, both of which were sorted; one of these lots was washed in clean water, and the other was not washed.

Test no. 3.—The fruit used was purchased from two growers, sorted, and divided equally into two lots of 16 pints each, the distribution being made as in test no. 1. One of these lots was washed in clean water; the other was not washed.

Further information concerning the handling of these tests and results of inspections in New York is given in table 4.

TABLE 4.—*Information concerning the handling and inspection at destination of test lots of strawberries shipped in precooled loads from Plant City, Fla., to New York, N. Y., 1932*

Test no.	Date shipped	Date of arrival	Time of inspection		Not washed			Washed in clean water		
			First	Second	Sound	Soft [1]	Decayed	Sound	Soft [1]	Decayed
					Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
1932-1 [2]	Feb. 29	Mar. 3	On arrival	After 2 more days at 70° F.	68.0	30.4	1.6	62.9	34.8	2.3
1932-2	Mar. 4	Mar. 6	After 1 day at 45° F.	After 2 more days at 45° to 50° F.	73.2	23.1	3.7	76.3	20.9	2.8
1932-3	do	do	After 12 hours at 45° F.	After 2 more days at 45° to 50° F.	78.5	18.4	3.1	69.2	25.3	5.5
Average					73.2	23.9	2.8	69.5	27.0	3.5

[1] See footnote 1, table 3.
[2] Crate removed from car at Philadelphia and shipped by open express to New York.

In the first and third tests the percentage of sound berries was largest in the lots that were not washed. In the second test the opposite condition was found. The differences in each case seem to have depended chiefly on variations in the percentage of soft berries rather than on variations in the percentage of decay. All of the tests dealt with fruit that had been sorted to remove decayed or otherwise damaged berries. They do not furnish evidence as to what can be expected when fruit that contains decay is washed. However, in the absence of definite information on this latter point, it seems safe to conclude from the results of the tests, that washing strawberries before packing brings about some damage because of the extra handling but does not cause decay to develop more rapidly during the usual transit period.

EFFECT OF WETTING ON RATE OF COOLING

In order to determine how the wetting of strawberries affects their rate of cooling and thereby influences the deterioration that takes place, studies were made at the cold-storage laboratory, Arlington Experiment Farm, Rosslyn, Va., on freshly picked berries. There were four test lots of 1 quart each; 2 quarts were dry and 2 were wet. One lot of each pair was held in still air, and the other two lots were placed in front of and about 4 feet away from a 14-inch electric fan running at such a speed that the rate of air movement over the berries averaged about 300 feet per minute. The temperature of the room where the tests were run ranged from 47.6° F. at the start to 40.3° at the end; during most of the time it was 41° to 42°, so that temperature conditions were fairly comparable with those existing in the upper part of a refrigerated carload of fruit during transit. The fruit temperatures at the top and bottom of each box and the air temperature above each box were obtained by means of thermocouples.

The results obtained during a run of approximately 15 hours are summarized in tables 5 and 6.

TABLE 5.—*Time required for strawberries, under different treatments, to reach a temperature of 45° in a room at approximately that temperature*

[Temperature of all lots at beginning of test, about 70° F.]

Box no.	Treatment	Time required at— Bottom of box		Time required at— Top of box	
		Hr.	*min.*	*Hr.*	*min.*
1	Dry, fan-blown	0	52	0	53
2	Dry, in still air	3	13	2	30
3	Wet, in still air	2	42	1	37
4	Wet, fan-blown	0	30	0	29

TABLE 6.—*Loss in weight in strawberries, under different treatments, during a period of 15 hours*

Box no.	Treatment	Net weight at beginning of test	Net weight after test	Shrinkage
		Ounces	*Ounces*	*Ounces*
1	Dry, fan-blown	17.25	10.75	6.5
2	Dry, in still air	17.0	13.5	3.5
3	Wet, in still air	17.5	14.0	3.5
4	Wet, fan-blown	17.5	10.5	7.0

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It will be noted that fan-blown berries cooled much more rapidly than those in still air, and that wet berries, either fan-blown or in still air, cooled somewhat faster than dry ones. Loss in weight was greatest in the fan-blown berries; however, the movement of air inside of a closed, loaded, refrigerator car does not attain a speed of 300 feet per minute except during the period of precooling. The results presented in tables 5 and 6 are therefore interesting merely as evidence that the wetting of strawberries hastens the rate at which they cool.

EFFECT OF TEMPERATURE ON FIRMNESS

During the 7 years, 1928–34, tests were made at Arlington Experiment Farm, Rosslyn, Va., to determine whether and in what way the firmness of strawberries is affected by the temperature at which they are held. Firmness was measured by means of a plunger-type pressure tester similar to the kind now widely used in this country for apples and pears (*7*), as well as by a squeeze tester designed by the junior author and described by Haller and his coworkers (*5*).

A review of the results of the 7-year work (*11*) indicates (1) that the plunger-type tester measures chiefly the toughness of the fruit and the squeeze tester the firmness of the flesh; (2) that cooling strawberries increases their resistance to puncturing, but has little effect on their resistance to crushing.

In these investigations evidence was obtained that strawberries are usually somewhat firmer at low temperatures than at high ones. The differences between the figures obtained for the various temperatures were generally so small, however, that they are not thought to be of any significance in the marketing of this fruit. The greatest benefit derived from refrigerating strawberries is its effect in controlling decay.

TRANSPORTATION OF STRAWBERRIES BY RAIL

Because of their well-known perishability, strawberries should be moved to market as quickly as possible after picking, under conditions that keep them as cool as possible. For this reason practically all strawberries moving in carload lots in the United States are shipped under refrigeration.

In 1931 and 1932 eight transportation tests were made from Plant City and Lawtey, Fla., which were accompanied from loading point to destination by Government observers. These tests comprised 25 cars, 16 of which were precooled. One of the cars (B, 1932–1) was a wooden refrigerator car; the other 24 were of the all-steel express refrigerator type which has now largely superseded wooden cars for the shipment of Florida strawberries. A record of fruit and air temperatures during precooling and the subsequent transit period was obtained by means of the electrical resistance thermometers described on page 12.

In 1935 studies on the precooling of strawberries were made at Plant City, using the same type of all-steel refrigerator cars as those in which the strawberry tests of 1931 and 1932 were made.

During these tests, fruit and air temperatures were taken in 11 loaded cars at intervals of about an hour during the precooling period, using the temperature equipment just mentioned. Six of the cars (A, B, C, D, E, H) were accompanied as far as Jacksonville by Government observers, temperature readings being made at Wildwood and Jacksonville. Temperatures were also obtained in five of the test cars (B, C, D, I, K) at various northern cities by means of either mercury thermometers or the electrical equipment.

All precooling of test cars was done either by the shipper or by a commercial precooling company at a stated price per car. Pertinent data concerning the construction of the cars is given in table 7.

The number and capacity of the crates in each load and the time when loading began and ended are given in tables 8 and 9.

TABLE 7.—*Details of construction of refrigerator cars used in strawberry transportation tests*

Item	Steel cars	Wooden car
Dimensions:		
Inside length between bulkheads	40 feet 2 inches	40 feet 10⅜ inches.
Inside width between side walls	8 feet 11 inches	7 feet 1⅝ inches.
Height, floor to ceiling	7 feet 8 inches	8 feet 6⅞ inches.
Bunker capacity in chunk ice ... pounds	14,300	11,900.
Loading space ... cubic feet	2,737	2,383.
Insulation:		
Sides and ends	4-inch Dry Zero	1 layer of 1-inch Flaxlinum and 1 layer of ⅜-inch Celotex, with inside and outside layers of insulating paper.
Floor	5½-inch Celotex or Insulite.	2-inch corkboard with 2 thicknesses of insulating paper.
Roof	4½-inch Dry Zero	1-inch Flaxlinum with top and bottom layers of insulating paper.
Other details of construction:		
Floor racks	Yes	Yes.
Bulkhead	Insulated, hinged, double-walled.	Insulated.
Superstructure	Steel	Wood.
Ceiling	Arched	Flat.
Bunkers	Basket type	Basket type.

TABLE 8.—*Loading data for 25 test carloads of strawberries shipped from Florida to Philadelphia and New York, 1931 and 1932*

Test no. and car	Date loaded	Time loading began	Time loading was completed	Number and capacity of crates [1]
1931-1:				
A	Mar. 14	12:01 p.m.	3:20 p.m.	480-36 pt. 434-36 pt.
B	do	11:15 a.m.	3:30 p.m.	41-32 qt. 1-60 pt.
C	do	5:00 p.m.	6:00 p.m.	494-36 pt. 3-24 qt. 42-32 qt.
1931-2:				
A	Mar. 24	5:00 p.m.	6:00 p.m.	133-36 pt. 175-32 qt. 56-24 qt.
B	do	12 noon	1:50 p.m.	350-36 pt. 42-32 qt. 56-32 pt.
1931-3:				
A	Apr. 14	10:40 a.m.	2:30 p.m.	280-32 qt.
B	do	3:20 p.m.	4:48 p.m.	280-32 qt.
C	do	11:15 a.m.	2:45 p.m.	266-32 qt. 33-36 pt.
1931-4:				
A	Apr. 21	12:01 p.m.	4:50 p.m.	280-32 qt. 16-36 pt.
B	do	9:30 a.m.	4:25 p.m.	280-32 qt.
C	do	11:00 a.m.	2:35 p.m.	280-32 qt.
1932-1:				
A	Feb. 26	11:30 a.m.	3:45 p.m.	480-36 pt.
B	do	2:00 p.m.	3:20 p.m.	480-36 pt.
C	do	12 noon	2:10 p.m.	480-36 pt.
D	do	11:45 a.m.	2:15 p.m.	480-36 pt.
1932-2:				
A	Mar. 19	11:30 a.m.	2:15 p.m.	545-36 pt.
B	do	2:30 p.m.	7:15 p.m.	508-36 pt. 28-24 pt.
C	do	12:15 p.m.	2:45 p.m.	480-36 pt.
1932-3:				
A	May 4	10:30 a.m.	1:00 p.m.	280-32 qt.
B	do	10:30 a.m.	11:25 a.m.	280-32 qt.
C	do	11:30 a.m.	2:00 p.m.	280-32 qt.
1932-4:				
A	May 9	10:15 a.m.	12:25 p.m.	280-32 qt.
B	do	10:00 a.m.	12:20 p.m.	280-32 qt.
C	May 10	12:10 p.m.	1:35 p.m.	280-32 qt.
D	do	12:30 p.m.	2:40 p.m.	280-32 qt.

[1] Loads 2 and 3 layers high. Occasionally an extra third or fourth layer at ends of car.

TABLE 9.—*Loading data for 11 test cars of strawberries shipped from Florida to northern markets, 1935*

Car	Date loaded	Time loading began	Time loading was completed	Number and capacity of crates [1]
A	Mar. 11	2:30 p.m.	4:15 p.m.	408-36 pt. 120-24 pt.
B	do	3:20 p.m.	5:50 p.m.	480-36 pt.
C	Mar. 16	2:30 p.m.	6:00 p.m.	528-36 pt.
D	do	2:45 p.m.	4:05 p.m.	480-36 pt.
E	Mar. 18	1:30 p.m.	6:55 p.m.	482-36 pt.
F	do	4:30 p.m.	6:55 p.m.	432-36 pt. 64-24 pt.
G	Mar. 18	12:30 p.m.	4:05 p.m.	480-36 pt.
H	do	12:30 p.m.	3:45 p.m.	400-36 pt. 64-24 pt. 68-32 qt.
I	Mar. 22	12 noon	5:30 p.m.	482-36 pt.
J	do	12:30 p.m.	3:15 p.m.	480-36 pt.
K	do	12:30 p.m.	3:15 p.m.	480-36 pt.

[1] Loads 3 layers high except in car H where there was an extra fourth layer in the ends of the car.

TEMPERATURE EQUIPMENT

As already mentioned (p. 10), electrical-resistance thermometers were used to obtain fruit and air temperatures within the cars. The sensitive part or "bulb" of the instrument was inserted into quart or pint cups of berries or hung in the air, at different locations in the car. Leads from these bulbs were connected to a master cable, which was carried out of the car through a thin door plate placed between the top of one of the doors and the insulating padding at the top of the doorway, and thence to the running board on top of the car. Readings were made by attaching the end of the master cable to an indicator or reading box equipped with a suitable selector switch by which the electrical resistance in any of the 12 bulbs could be determined. The indicator box is a modified Wheatstone bridge utilizing a sensitive galvanometer. Changes in the temperature of the bulb produce corresponding changes in the resistance of the coil in the bulb, which the reading box indicates directly in degrees Fahrenheit. Since slight variation exists in the different instruments, calibration of individual bulbs and individual indicators is necessary. The instruments are so constructed and placed that temperature readings may be obtained at a number of locations inside the car without opening the doors.

The bulb is a nickel and manganan coil encased in a small, nickel-plated, cone-pointed brass tube. It is not possible to get the bulb lodged entirely in one fruit of peaches, cherries, or berries, hence in tests with these fruits the indicated "fruit" temperature probably lies somewhere between the true fruit temperature and the temperature of the surrounding air. It is therefore advisable to record air temperature adjacent to the material being tested when one of the fruits mentioned above is under observation, so that irregularities can be accounted for when they occur. This was done in the tests considered in this bulletin. However, the temperature of strawberries in crates changes quite readily with that of the surrounding air, hence when the temperature of the air surrounding the fruit in two cars is practically constant during a fairly long period, the temperature of the fruit in those cars should not be radically different during the same period.

A master cable was placed in one end of each of the cars used in the 1931 and 1932 tests. The 12 bulbs from this cable were located along the center line of the load in such a way that it was possible to obtain fruit and air temperatures of the top and bottom, at the bunker, quarter-length, and doorway positions. During the 1932 investigations one car in each test contained one or two extra cables, the bulbs of which were located in the fruit or air along the side of the load or at various levels above it. During the 1935 tests one car had an extra cable, the bulbs of which were in the fruit or air at the top of the bottom layer and the top of the second layer, at the bunker, quarter-length, and doorway positions.

With the exception of those on the extra cable referred to above, the thermometer bulbs for recording fruit temperature were placed in the bottom layer of bottom crates and in the top layer of top crates; those for air temperatures were hung just outside the same crates on a level with the bulbs for recording fruit temperature.

TEST FRUIT

Test fruit, prepared as described on page 7, was placed at various positions in 21 of the cars used in the transportation tests of 1931 and 1932. This fruit was examined at destination to determine the effect of the various methods of precooling and transit refrigeration. The results of the inspections are discussed on pages 50 to 52.

There was no test fruit in 1935.

THE REFRIGERATOR CAR

Refrigeration in cars is made possible by insulation in the floor, walls, and roof of the car and, in most refrigerator cars, by the melting of ice placed in the bunkers. The heat present in the load comes from two different sources: (1) Sensible heat which existed in the car before loading, and in the commodity and the containers when they were placed in the car; (2) the heat produced by the commodity itself as a result of its own respiration. If the commodity is hot when loaded, the cooling is slow, and the quantity of heat from this second source may be rather large. Calculations based on reliable data show that during a 48-hour trip from Florida to northern markets the heat of respiration in a carload of four hundred and eighty 32-quart crates of strawberries (about 7 tons of fruit) may be great enough to melt half a ton of ice.[4]

If the fruit and containers have a temperature of 80° F. when placed in the car, the sensible heat which must be removed from 7 tons of fruit in order to cool it to 40°, for example, is great enough to melt about 1¾ tons of ice. The total ice required merely to cool the load from 80° to 40° will therefore amount to about 2¼ tons, even if no allowance is made for ice needed to absorb the heat that must be removed from the car itself and the heat that enters it from the outside. The latter will of course be much the larger when the outside temperature is high. How much of it there will be depends on a number of factors, chief among which are the length of time the car is in transit, the method of insulation, the temperature of the fruits or vegetables when loaded, and the difference between inside and outside temperatures throughout the trip.

[4] Calculated from data given by Haller and his coworkers (*4*).

RATE OF COOLING

It is sometimes assumed that as soon as the doors are closed on a load of strawberries or other produce in an iced refrigerator car, the load is almost immediately cooled to the approximate temperature of the ice. If this assumption is made it is easy to make the further assumption that any deterioration of the load in transit is caused by inadequate icing or a faulty condition of the car.

This is not true with strawberries nor with any other commodity. Cooling is gradual, and several hours to a day or two may be required to reduce the temperature of the load to that of the air in the cars. The rate of cooling depends chiefly on the difference between the two temperatures, but is also affected by the quantity of the commodity

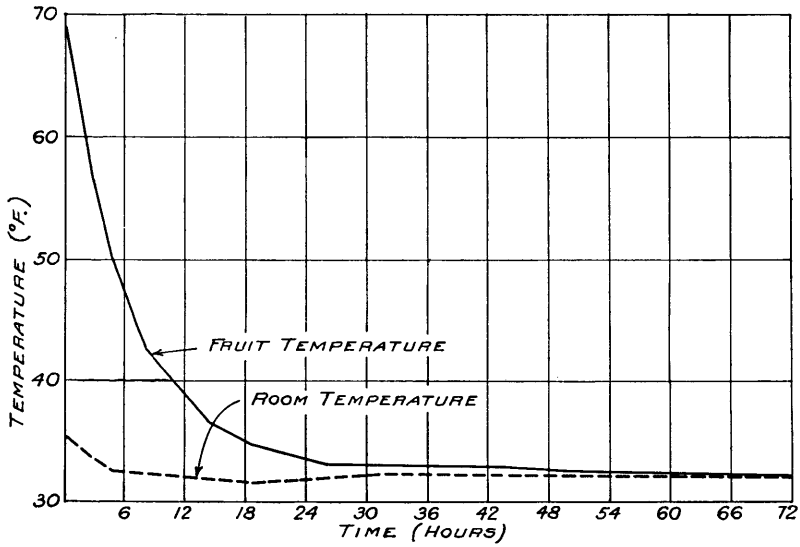

FIGURE 5.—Rate of cooling in a crate of Premier strawberries in a cold-storage room held at approximately 32° F.

to be cooled, the kind of container and the method of stacking or loading the packages in the car.

Figure 5 illustrates what happens when a crate of strawberries is placed in a cold-storage room held at 32° to 35° F.

It will be observed that the most rapid cooling occurred during the first 8 hours; that the rate of cooling became gradually slower as the test was continued and the temperature of the room and the fruit approached each other; and that the fruit was still about 2° warmer than the air in the room, even at the end of 24 hours.

The rate of cooling a carload of strawberries is, of course, much slower than that shown in figure 5 for a single crate. Figure 6 illustrates the results obtained under standard refrigeration with 3 percent of salt at all icing stations, and shows clearly that the fruit in this car required considerable time to cool. In all parts of the load where temperatures were taken, it cooled most rapidly during the first 18 hours after loading was completed. The fruit at the bottom of the car required approximately 22 hours to reach 30° F. The fruit at the top did not go below about 38° during the entire transit period, while it required 13½ hours to reach 50° and 39½ hours to reach 38°. This car was shipped March 24, and the outside temperature when loading was completed was 69°. The average temperature of the top fruit was 60.4° and of the bottom fruit 47.5°.

EFFECT OF CHANGES IN OUTSIDE TEMPERATURE

If shipments of perishable commodities like strawberries are kept properly refrigerated in transit they never show the marked fluctuations in temperature that occur outside the car. The lag in tempera-

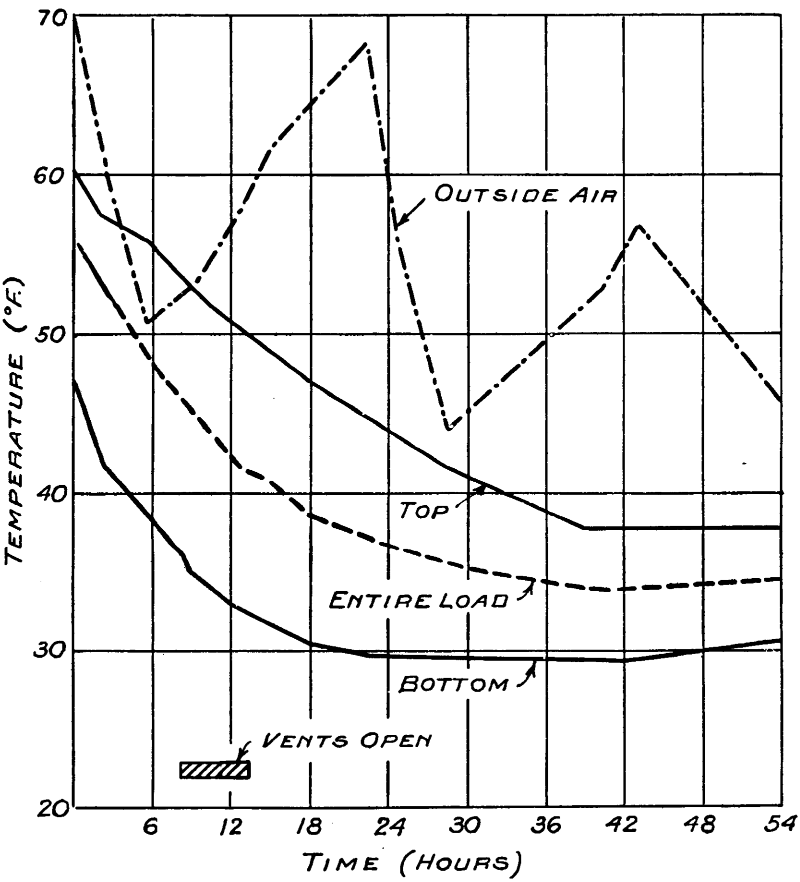

FIGURE 6.—Average fruit temperatures in the top and bottom layers and average temperature of entire load in a test carload of strawberries shipped from Plant City, Fla., to Philadelphia, Pa., March 24, 1931. Test 1931-2.

ture changes in the load due to changes in outside temperature may be several hours, as shown in figure 7 (cars A and C, 1932-2).

During the second 12 hours of the test, and while the outside temperature rose 32° F., the top-fruit temperature rose only about 2° in car A and about 1° in car C. Toward the end of the trip the average top-fruit temperature fell only about 1° while the outside temperature was dropping 10.5°. On the other hand, the average top-fruit temperature in car A rose approximately 3.5° during a time when the

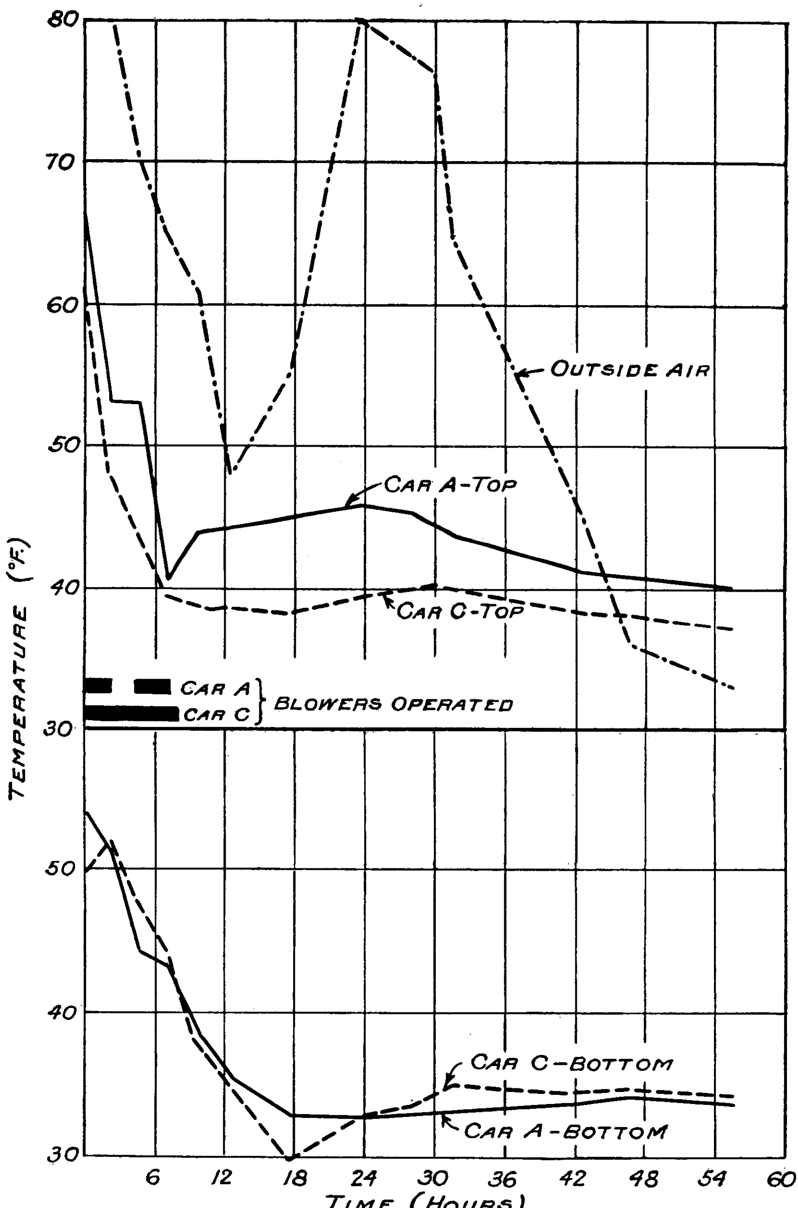

FIGURE 7.—Average top and bottom fruit temperatures in two test carloads of strawberries shipped from Plant City, Fla., to New York, N. Y., and Philadelphia, Pa., March 19, 1932. Test 1932-2.

outside temperature fell 4°. This illustrates the fact shown for car A, 1931–32 (fig. 7), and for other cars used in these tests, that changes in fruit temperatures are frequently the opposite of those occurring in the outside temperatures. In car A, 1931–2 (fig. 7) the average fruit temperature at both top and bottom continued to fall for about 12 hours while the outside temperature rose from 51° to 65°; toward the end of the trip it remained fairly constant in the bottom layer and dropped about 4° in the top layer during a period when the outside temperature rose 13°. In this and other tests it was found that during the period of rapid cooling, there are few marked changes in inside temperatures that can be traced to changes in outside temperature.

METHODS OF ANALYZING TEMPERATURE DATA

The fruit temperatures recorded during the precooling and transportation tests under discussion were obtained at several different places in each test car. They indicate fairly well the temperature changes that occurred in the part of the load near the location of each thermometer, during the transit period. However, in order to study the effect of precooling and of various methods of transit refrigeration it is necessary to have a figure representing the average temperature of the whole load at a given time or throughout the transit period.

Because of the way in which strawberries are loaded, in Florida as well as in many other strawberry-producing sections, it is difficult to obtain such an average value and at the same time have it accurate and reliable. In most instances a carload comprises a large number of small lots from many growers who have delivered their fruit to the car at intervals during a period of 1 to 7 hours (tables 8 and 9). Under such conditions the temperature of the fruit is likely to vary greatly in different parts of the load, so that if average temperatures are computed, any conclusions based on them should take account of possible errors inherent in them.

AVERAGE TEMPERATURE OF LOAD

During investigations by the United States Department of Agriculture on the transportation of oranges from California (*8*), it was found that the average fruit temperature at the top and bottom quarter-length positions at any given time represents quite accurately the average temperature of the whole load.

In the Florida strawberry transportation investigations it was similarly found that the average fruit temperature at the top and bottom quarter length may be regarded as the approximate average temperature of the whole load. Table 10 shows the values for the whole transit period obtained by averaging all the fruit temperatures available in pairs (top and bottom) for each car and the average fruit temperatures at the top and bottom quarter-length positions. The table also contains values for the average temperature of the load for the whole transit period as calculated by the method used by Mann and Cooper (*8*). In several instances the values found for each car by the two methods are very nearly the same. In no instance do they differ by more than 2.7° F.

TABLE 10.—*Average temperature of carloads of strawberries at various times during the transportation test*

[Cars contained more than the usual number of electrical resistance thermometers]

Test no. and car	Average of all paired temperatures				Average of temperatures at top and bottom quarter-length positions			
	At beginning of test	At end of precooling	At end of test	For whole transit period	At beginning of test	At end of precooling	At end of test	For whole transit period
	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.
1932-2:								
A [1]	60.2	41.0	36.8	40.5	60.8	42.5	37.0	41.2
1932-3:								
C [2]	65.0	58.3	39.5	46.7	67.7	56.5	38.3	45.2
1932-4:								
A [2]	70.9	51.1	37.6	45.4	68.4	52.1	38.9	45.8

[1] 10 temperatures.
[2] 14 temperatures.

TABLE 11.—*Information concerning the loading, precooling, and transit refrigeration York, 1931*

Test no. and car	Date loaded	Time loading was completed	Time in transit	Time car precooled	Average outside temperature during test	Average temperature of fruit when loading was completed			Average temperature of fruit at destination		
						Top	Bottom	Entire load	Top	Bottom	Entire load
1931-1:					° F.	° F.	° F.	° F.	° F.	° F.	° F.
A	Mar. 14	3:20 p. m.	53 h.	5 h. 40 m.	52.9	64.5	60.0	65.6	38.1	35.4	38.0
B	do	3:30 p. m.	52 h. 50 m.	4 h. 55 m.	54.0	69.1	57.4	61.6	40.8	35.3	37.7
C	do	6:00 p. m.	50 h. 20 m.	Not precooled	53.0	70.7	57.7	63.4	40.8	35.5	38.0
1931-2:											
A	Mar. 24	6:00 p. m.	53 h. 50 m.	do.[2]	55.2	60.4	47.4	56.1	37.8	30.8	34.6
B	do	1:50 p. m.	56 h. 5 m.	4 h. 30 m.	54.1	63.8	46.9	56.6	41.7	35.1	37.3
1931-3:											
A	Apr. 14	2:30 p. m.	33 h.	Not precooled [4]	61.0	67.4	51.5	61.6	46.2	34.0	38.8
B	do	4:48 p. m.	30 h. 50 m.	do.[6]	62.4	68.1	53.1	60.9	41.8	32.8	36.6
C	do	2:45 p. m.	32 h. 45 m.	do	61.0	68.0	51.0	64.0	42.7	36.2	38.3
1931-4:											
A	Apr. 21	4:50 p. m.	34 h. 35 m.	do	59.0	68.5	(7)	(7)	41.7		
B	do	4:25 p. m.	35 h. 15 m.	do.[9]	59.2	70.4	(7)	(7)	39.9		
C	do	2:35 p. m.	36 h. 50 m.	do	59.0	72.2	(7)	(7)	39.1		
1932-1:											
A [10]	Feb. 26	3:45 p. m.	62 h. 30 m.	5 h. 57 m.	59.0	64.3	48.8	57.0	40.8	35.2	38.6
B	do	3:20 p. m.	53 h.	6 h. 20 m.	57.7	62.1	58.0	61.6	37.0	32.4	35.3
C	do	2:10 p. m.	53 h. 50 m.	8 h. 20 m.	57.3	70.0	50.9	(11)	37.7	33.6	
D	do	2:15 p. m.	54 h. 45 m.	7 h. 40 m.	59.6	(11)	51.3	(11)	38.2	35.0	
1932-2:											
A	Mar. 19	2:15 p. m.	55 h. 15 m.	5 h. 15 m.	58.2	66.2	53.9	60.8	40.0	33.7	37.4
B	do	7:15 p. m.	51 h. 15 m.	3 h. 55 m.	55.7	63.7	46.5	58.2	37.9	33.2	36.2
C	do	2:45 p. m.	55 h. 15 m.	8 h. 3 m.	59.5	61.2	49.5	58.8	37.3	34.3	36.4
1932-3:											
A	May 4	1:00 p. m.	32 h. 15 m.	2 h. 25 m.	71.6	69.5	54.9	63.5	44.5	30.9	36.9
B	do	11:25 a. m.	33 h. 35 m.	4 h. 10 m.	72.0	56.5	49.0	57.6	41.1	31.8	35.7
C	do	2:00 p. m.	31 h. 15 m.	Not precooled [12]	70.5	70.5	55.6	64.5	45.5	32.2	38.3
1932-4:											
A	May 9	12:25 p. m.	32 h. 55 m.	4 h. 18 m.	70.1	78.0	61.2	68.5	43.4	30.3	37.5
B	do	12:20 p. m.	33 h. 10 m.	4 h. 3 m.	71.8	70.0	53.8	67.3	42.6	28.2	34.4
C	May 10	1:35 p. m.	55 h. 15 m.	9 h. 20 m.	70.0	75.3	66.6	76.2	37.8	28.5	33.9
D	do	2:40 p. m.	54 h. 25 m.	9 h. 30 m.	69.4	79.5	65.4	71.3	38.5	28.7	34.1

[1] After 5 hours 40 minutes.
[2] Vents open to Ocala, Fla., 5 hours.
[3] After 4 hours 30 minutes.
[4] Vents open 2 hours 30 minutes, during loading.
[5] After 5 hours 20 minutes.
[6] Vents open to Thalmann, Ga., 5 hours 20 minutes.
[7] No bottom-fruit temperatures recorded.

Another basis of comparison that can be used is the quantity of heat removed from the shipment during the test. This can be calculated by using the figure for the average temperature of the load, as determined by the method already described. Table 11, based on the investigations of 1931 and 1932, presents the results of such calculations, together with the temperature data from which they were derived, and such other information as seems necessary for an interpretation of the differences shown. The total heat removed by the melting of the ice includes the heat removed from the fruit, the containers, and the car, the heat of respiration, and the heat that enters the car from the outside (heat leakage).

of 25 test carloads of strawberries shipped from Florida to Philadelphia and New and 1932

Average temperature of fruit at end of precooling period			Average drop in fruit temperature during test			Average drop in fruit temperature during precooling period			Average temperature of fruit during test			Ice-meltage equivalent of total heat removed	Total ice meltage	Ice-meltage equivalent of heat leakage	Ice-meltage equivalent of heat removed per ton of load
Top	Bottom	Entire load	Top	Bottom	Entire load	Top	Bottom	Entire load	Top	Bottom	Entire load				
° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	Lb.	Lb.	Lb.	Lb.
46.7	49.5	48.5	26.4	24.6	27.6	17.8	10.5	17.1	43.8	39.8	43.0	3,316	9,175	5,859	383
50.3	50.5	49.2	28.3	22.1	23.9	18.8	6.9	12.4	46.3	38.9	42.8	3,126	6,666	3,540	342
[1] 65.0	[1] 44.5	[1] 52.5	29.9	22.2	25.4	[1] 5.7	[1] 13.2	[1] 10.9	50.9	37.7	42.9	3,558	6,068	2,510	346
[3] 56.3	[3] 40.5	[3] 50.0	22.6	16.6	21.5	[3] 4.1	[3] 6.9	[3] 6.0	44.6	32.3	38.9	2,672	9,812	7,140	288
46.9	40.0	42.4	22.1	11.8	19.3	16.9	6.9	14.2	45.0	36.5	39.7	2,556	11,866	9,310	281
[5] 62.5	[5] 41.0	[5] 54.7	18.0	17.5	22.8	[5] 4.9	[5] 10.5	[5] 6.9	53.5	36.7	46.6	2,788	5,950	3,162	316
[5] 62.0	36.5	[5] 48.5	26.3	20.3	24.3	[5] 6.1	[5] 16.6	[5] 12.4	53.0	35.2	46.3	2,878	6,512	3,634	326
63.8	39.6	[5] 54.8	25.3	14.8	25.7	[5] 4.2	[5] 11.4	[5] 9.2	53.0	36.5	46.8	3,112	6,275	3,163	348
[8] 64.5	------	------	26.8	------	------	[8] 4.0	------	------	52.5	------	------	------	9,090	------	------
[8] 63.8	------	------	30.5	------	------	[8] 6.6	------	------	51.1	------	------	------	10,429	------	------
[8] 63.8	------	------	33.1	------	------	[8] 8.4	------	------	49.4	------	------	------	8,852	------	------
43.5	38.7	38.0	23.4	13.6	18.4	20.8	10.1	19.0	43.4	35.8	39.0	2,422	6,090	3,668	281
40.2	45.5	40.3	25.1	25.6	26.3	21.9	12.5	21.3	41.5	36.5	39.4	3,006	10,157	7,151	347
42.1	41.5	------	32.3	17.3	------	27.9	9.4	------	42.2	35.5	------	------	------	------	------
40.6	42.3	------	([11])	16.3	------	([11])	9.0	------	([11])	35.5	------	------	------	------	------
41.0	41.5	42.5	26.2	20.2	23.4	25.2	12.4	18.3	48.8	35.9	41.2	3,274	12,837	9,563	333
49.0	46.5	48.0	25.8	13.3	22.0	14.7	0	10.2	44.4	34.1	39.9	2,990	9,947	6,957	315
39.0	42.0	39.0	23.9	15.2	22.4	22.2	7.5	19.8	39.5	35.9	38.3	2,668	10,356	7,688	308
60.0	53.0	54.5	25.0	24.0	26.6	9.5	1.9	9.0	53.6	37.0	44.7	3,074	8,273	5,199	348
45.0	46.0	48.5	15.4	17.2	21.9	11.5	3.0	9.1	45.3	34.0	40.7	2,524	8,866	6,342	286
[13] 65.7	[13] 42.0	[13] 53.5	25.4	23.4	26.2	[13] 4.8	[13] 13.6	[13] 11.0	55.4	35.4	45.2	3,041	7,430	4,389	344
55.6	51.2	51.7	34.6	30.9	31.0	22.4	10.0	16.8	54.3	37.7	45.8	3,516	9,188	5,672	398
57.0	53.5	55.8	27.4	25.2	32.9	13.0	.7	11.5	52.1	36.6	44.2	3,680	9,650	5,970	417
44.0	44.0	47.3	37.5	38.1	42.3	31.3	22.6	28.9	46.1	36.1	41.9	4,828	11,988	7,160	547
47.7	45.6	47.8	41.0	36.7	37.2	38.5	19.8	23.5	48.2	36.1	42.0	4,324	12,236	7,912	491

[8] After 4 hours.
[9] Vents open to Jacksonville, Fla., 4 hours.
[10] 1932–1 car A, wooden.
[11] No fruit temperatures recorded at top quarter length.
[12] Vents open to Jacksonville, Fla., 2 hours 15 minutes.
[13] After 4 hours 10 minutes.

The heat removed from the car is not easily calculated but is assumed to constitute a small part of the heat leakage. The assumption is also made that the sum of the two (expressed as "heat leakage", in table 11, can be found by subtracting the ice-meltage equivalent [5] of the other heat removed (heat of respiration and heat removed from the fruit and the containers) from the total ice meltage.

The loads in the test cars were not all of the same weight, consequently the figures for heat removed are still not strictly comparable. To make them so it is necessary to express them in terms of heat removed (or its ice-meltage equivalent) per ton of load. This is done in the last column of the table.

AVERAGE TEMPERATURE OF TOP AND BOTTOM LAYERS

Besides considering each carload as a whole, it is possible and often desirable to consider the top and bottom layers of each load separately. Top-layer temperatures under any kind of transit refrigeration without precooling are generally higher than those in the bottom layer; hence, it is desirable to know how temperatures in each layer are affected by the various kinds of treatment given to each car during precooling and in transit. Information on this point for the first 2 years' work is also given in table 11. In preparing these data, no attempt was made to calculate quantities of heat removed from each layer.

In table 11 and elsewhere in this bulletin the term "time in transit" means the time from the completion of loading to the taking of the final temperature reading at destination. The average outside air temperatures were calculated by the method used for obtaining average fruit temperatures (p. 17). Temperatures entered under the headings "Average temperature of fruit at precooling period" and "Average drop in fruit temperature during precooling period" for the nonprecooled cars are the ones that existed in those cars either at the time when the vents were closed or when precooling stopped in some other car. For details, see the footnotes below the table. Differences between corresponding temperature values in top and bottom layers are considered significant if they amount to 1° or more.

Table 12 presents information concerning the loading and precooling of the 11 test cars used in 1935, organized in the same way and subject to the same limitations as that given in table 11. Additional information concerning 8 of the test cars of 1935 is presented in table 13.

[5] The heat was originally calculated as British thermal units. If any figure so obtained is divided by 144, the quotient is the number of pounds of ice that the given quantity of heat would melt and is here termed its "ice-meltage equivalent."

TABLE 12.—*Information concerning the loading and precooling of 11 carloads of strawberries shipped from Florida to northern markets in 1935*

Car	Date loaded	Average temperature of outside air during test	Average temperature of fruit at time of loading	Time loading was completed	Length of precooling period		Precooling apparatus	Salt added during precooling	Average temperature of fruit when loading was completed			Average temperature of fruit at end of precooling			Average drop in fruit temperature during precooling			Average temperature of fruit during precooling			Total ice added during precooling	Ice-meltage equivalent of heat removed	Ice-meltage equivalent of heat removed per ton of load
									Top	Bottom	Entire load [1]	Top	Bottom	Entire load [1]	Top	Bottom	Entire load [1]	Top	Bottom	Entire load [1]			
		°F.	°F.		Hr.	min.		Lb.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	Lb.	Lb.	Lb.
A	Mar. 11	77.1	76	4:40 p. m.	5	50	2 16-inch fans	400	75.8	59.8	70.9	32.4	38.2	39.0	43.4	21.6	31.9	43.4	48.9	50.2	4,800	3,296	373
B	do	75.6	76	6:00 p. m.	6	15	2 12-inch fans	400	74.1	56.2	69.3	36.4	39.4	37.7	37.7	16.8	31.6	47.1	48.1	48.4	3,200	3,220	370
C	Mar. 16	69.4	71	6:00 p. m.	5	30	4 12-inch fans	400	69.9	49.6	61.6	36.4	38.0	42.6	33.5	11.6	19.0	45.8	45.0	54.6	3,800	2,284	243
D	do	74.0	71	4:05 p. m.	5	53	2 16-inch fans	400	71.3	62.2	68.2	32.6	39.0	37.5	38.7	23.2	30.7	51.0	55.1	53.8	5,300	3,108	359
E	Mar. 18	69.0	75	6:55 p. m.	4	50	4 bunker blowers	600	67.9	49.9	58.3	46.6	44.5	48.7	21.3	5.4	9.6	54.0	49.5	53.2	6,100	918	105
F	do	70.5	74	6:55 p. m.	4	50	2 16-inch fans	400	72.4	62.6	71.3	34.6	39.9	45.1	37.8	22.7	26.2	43.0	49.2	56.0	5,100	2,686	313
G	do	75.4	74	4:05 p. m.	5	15	4 12-inch fans	400	71.4	51.4	63.7	35.1	35.1	41.0	36.3	16.3	22.7	48.1	43.8	55.2	6,100	2,412	279
H	do	79.5	74	3:45 p. m.	8	15	2 16-inch fans	400	73.5	52.3	64.9	33.1	37.5	39.6	40.4	14.8	25.3	46.4	47.5	49.6	6,100	3,300	322
I	Mar. 22	77.2	78	5:30 p. m.	6	35	2 12-inch fans	600	77.3	50.9	65.4	38.2	40.1	36.2	39.1	10.8	29.2	44.6	45.2	49.1	4,800	3,384	356
J	do	81.7	78	3:15 p. m.	7	35	2 16-inch fans	400	73.1	54.3	65.8	35.4	37.2	35.2	37.7	17.1	30.6	46.5	44.1	44.2	4,800	3,050	353
K	do	77.0	78	3:15 p. m.	7	10	2 16-inch fans	400	76.4	55.5	67.6	36.9	36.0	33.7	39.5	19.5	33.9	45.0	50.0	37.1	6,100	3,298	381

[1] The figures in this column are not averages of the figures for top and bottom layers in this table. For the method of obtaining them see p. 8.

TABLE 13.—*Average fruit temperatures at the end of precooling, and at various intervals thereafter, in 8 test carloads of strawberries shipped from Florida to northern markets, 1935*

Car	Average fruit temperature									
	At end of precooling		At Wildwood, Fla.		At Jacksonville, Fla.		At Washington, D. C.		At Cincinnati, Ohio	
	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*
A	32.4	38.2	38.8	37.0	39.8	32.6				
B	36.4	39.4	39.8	36.9	40.4	35.2	38.8	34.2		
C	36.4	38.0	35.9	33.3	38.9	30.8	38.9	34.8		
D	32.6	39.0	38.8	39.1	40.2	33.9	41.2	36.2		
E	46.6	44.5	48.0	37.8	46.0	36.2				
H	33.1	37.5	41.1	32.6	42.2	30.7				
I[1]	38.2	40.1							39.0	36.0
K	36.9	36.0							40.6	36.6

[1] Bottom bulkhead openings papered.

PRECOOLING

The normal movement of air in a closed, loaded, and iced refrigerator car (fig. 8, *A*) is downward around the ice in the bunkers, along the floor toward the doorway, upward toward the top of the car,

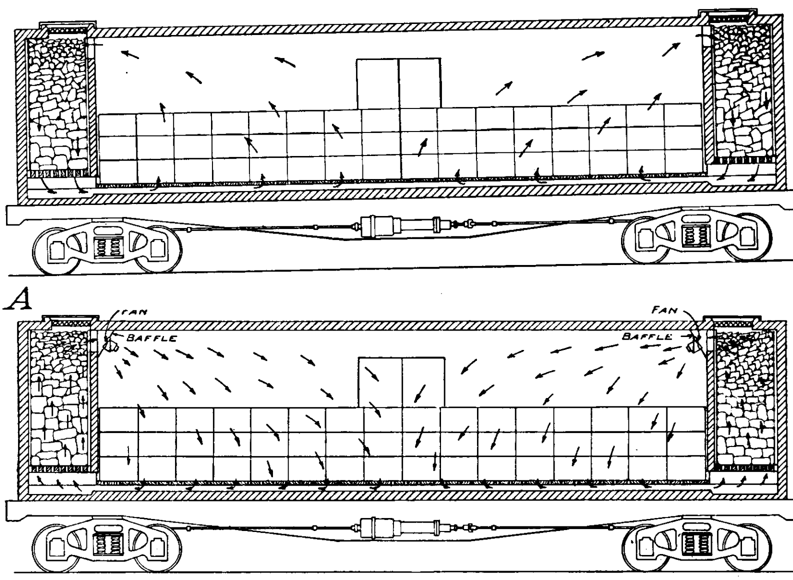

FIGURE 8.—Longitudinal section of loaded and iced refrigerator car showing (*A*) normal circulation of air, (*B*) reversed and augmented circulation of air produced during precooling by fans installed at the top bulkhead opening.

toward the bunkers, and down over the ice again. This movement depends upon the difference in weight between the cold, heavy air in the bunkers and the warm, light air elsewhere in the car, and is very slow. It can be hastened to some extent by adding salt to the ice which cools the load more rapidly because of the rapid removal of heat by the moving air. The rate of air movement and the consequent cooling can be hastened much more by using some mechanical method, as soon as the car is loaded, that will force the air rapidly over the ice in the bunkers and through the load. Such an operation is known as precooling. It is especially valuable with strawberries and other highly perishable fruits that must be moved with minimum delay after picking and are practically never given a warehouse precooling, even in rare instances when facilities are available.

KINDS OF PRECOOLING APPARATUS

Various kinds of precooling apparatus have been developed and are now used, but the most common ones can be described as follows:

(1) A device developed by the United States Department of Agriculture,[6] which consists of a blower connected with a small motor. The whole unit is of such size and weight as to be easily handled by one or two men (fig. 9). It will be referred to hereafter as the "bunker blower." Two or four units are installed in the hatchways on the ice at the tops of the bunkers of the car to be precooled, with the air-delivery tube of each blower pointing toward the center of the car. When the blowers are started the air in the car is caused to circulate upward and around the ice in the bunkers, thence out over the top of the load, downward to the floor, and along the floor to the bottom of the bunker where it begins the cycle again (fig. 8, *B*). This is just the reverse of the way in which the air usually or normally moves in an iced refrigerator car. It has the very desirable effect of causing the most rapid cooling in the part of the load where it is most needed, namely, in the upper, warmer layers. If continued long enough it is very effective in bringing all parts of the load to a good carrying temperature.

The best results have been obtained with this apparatus by closing the top bulkhead openings with sheathing or building paper, except immediately in front of the blower discharges. The paper of course should be removed when precooling is stopped.

This device was the forerunner of a number of others which have since been developed to utilize the principle of reversing the normal air circulation in a refrigerator car.

(2) Pressure-type fans (fig. 10) driven by ½- or ¾-horsepower motors. These fans are installed on the inside of the car at the upper bulkhead opening, and held in place by various devices. A baffle made of board-form material on a light wooden frame surrounds the fan and extends between the walls of the car from the roof to a line 3 or 4 inches below the base of the fan.

A two-fan baffle in place is shown in figure 11. In most cars two fans are used, one at each bunker. When four fans are used (two at each end), baffles that have two openings are required. When the baffle is in place a strip of canvas fastened along the lower edge is tacked to the bulkhead of the car and thus helps to insure that most of the air driven over the load by the fan will be drawn from the top of the bunker.

(3) A galvanized-iron sleeve in which a motor and fan are mounted This equipment is set on the ice in the hatchway and is connected with the upper part of the bulkhead screen by means of a canvas elbow. Used in Louisiana in 1933.

[6] GALLOWAY, A. G. A PORTABLE PRECOOLING APPARATUS. U. S. Dept. Agr., Bur. Plant Indus., 5 pp., illus. 1929. [Mimeographed.]

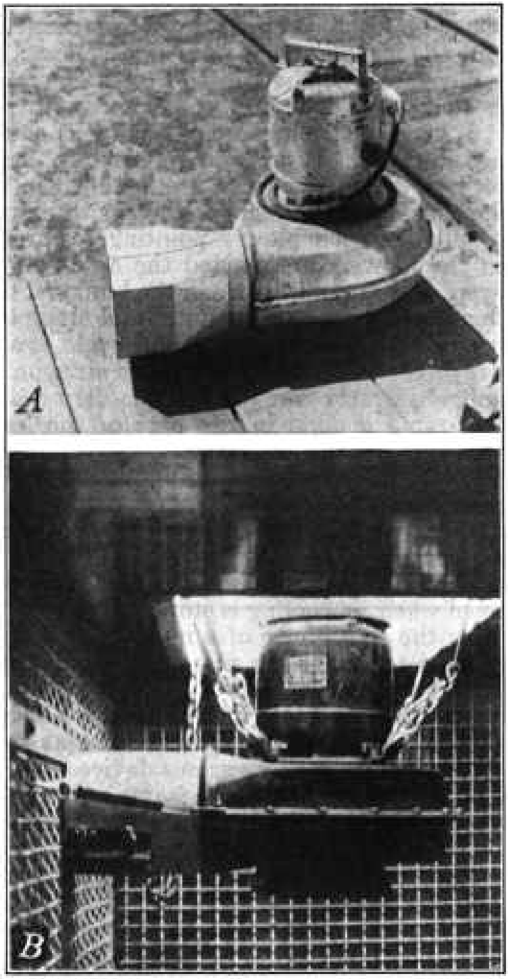

FIGURE 9.—*A*, Bunker blower. Air-delivery pipe with rectangular cross section. *B*, Bunker blower suspended just below hatchway of car, with air-delivery pipe directed toward top bunker opening. Pipe has circular cross section.

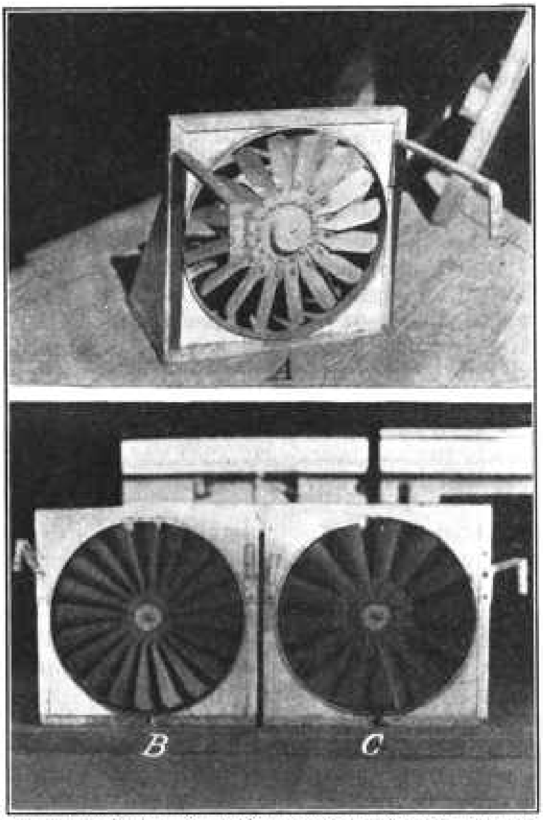

FIGURE 10.—Pressure-type fans: *A*, 12-inch fan; *B*, 20-blade 16-inch fan; *C*, 14-blade 16-inch fan.

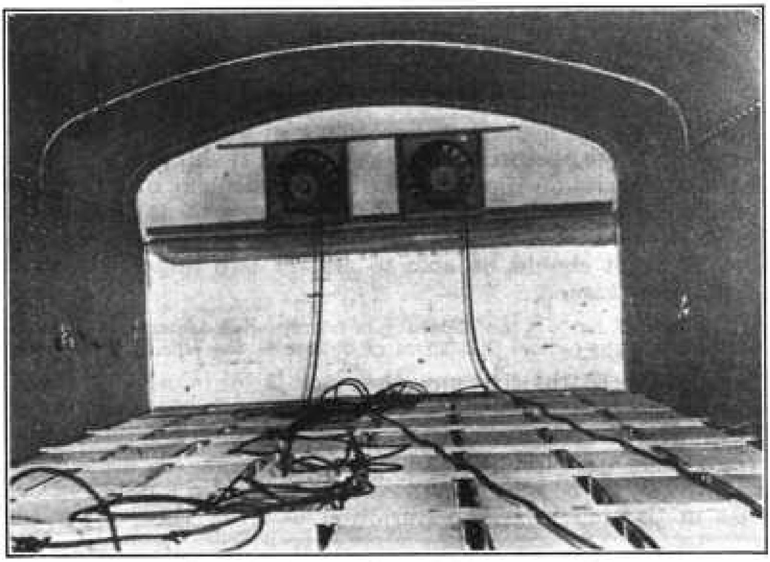

FIGURE 11.—Baffle and two fans in place at top of bulkhead.

(4) A single-walled canvas duct, extending from bunker to bunker between diagonally located hatchways, over the roof of the car. The motor and blower are inside the duct at one end. Used in Louisiana in 1933.

Nos. 1, 2, and 3 reverse the air circulation; no. 4 does not. The efficiency of types 1 and 2 was studied in these investigations.

GROWTH OF PRACTICE OF PRECOOLING

The device developed by the United States Department of Agriculture, no. 1 above, was first tested with strawberries under commercial conditions at Marston, N. C., in 1928. Other tests of this device were made that year on the Chesapeake Peninsula (Virginia) and in North Carolina. So far as known, commercial use of the apparatus did not begin until 1930 when car precooling was tried out in a small way by shippers in all three of the States mentioned. No information is available as to what other precooling devices were used commercially in that year. By 1931 car precooling by means of various devices had become rather common in Florida, but during the transportation investigations of that year it was still possible to obtain nonprecooled cars for comparison with precooled cars. In 1932, or only 2 years after its first commercial use, car precooling had become so general that a nonprecooled car could be obtained for only one test, namely, 1932–3, originating at Lawtey, Fla. In 1934 about 93 percent of the carlot shipments were precooled, and in 1935, so far as known, no cars of strawberries were shipped from Florida without being precooled. It is not often that such a fundamental change in the marketing of a crop takes place so quickly.

In other strawberry sections of the eastern and southern United States, particularly in Louisiana, precooling of carlot shipments is so common that it can almost be considered practically standard practice. The Bureau of Agricultural Economics of the United States Department of Agriculture [7] estimates that during the season of 1934, 80 percent of the strawberry shipments moving from Louisiana were precooled. In 1935 about 83 percent were precooled.

FACTORS AFFECTING EFFICIENCY OF PRECOOLING

The commercial use of car precooling of strawberry shipments is likely to give disappointing results at times, if shippers fail to realize how great a variation there may be in the efficiency of different kinds of precooling apparatus, and of the same kind of apparatus used in different ways. Anyone who wishes to use precooling intelligently and with profit should be able to answer two important questions concerning it, namely:

(1) Upon what basis is the efficiency of a precooling apparatus to be judged?
(2) What are the factors that affect or determine the efficiency of precooling?

The answer to the first question can be obtained by securing a record of the rate at which the apparatus cools the load, especially the top layer. This can be done fairly accurately with special fruit thermometers (resembling the clinical thermometers used by physicians) which can be inserted into the centers of a number of cups of berries in the top layer. Naturally, the lower the temperature in

[7] COOPER, M. R., and PARK, J. W. FACTORS AFFECTING RETURNS TO LOUISIANA STRAWBERRY GROWERS. U. S. Dept. Agr., Bur. Agr. Econ., 64 pp. 1934. [Mimeographed.]

these cups and the greater the drop from the loading temperature, the better is the job of precooling.

Information on the factors that affect or determine the efficiency of precooling is furnished by the results obtained during these investigations, most of which are summarized in tables 11 and 12. The bunker blowers were used in all of the 1931 and 1932 test cars except one, which was precooled with an apparatus that is now obsolete.

It will be of interest first of all to compare the results obtained by precooling without transit icing, and by standard refrigeration plus salt, but without precooling, as in cars A and C, test 1931–1. The pertinent data are given in table 14 and figure 12.

TABLE 14.—*Fruit temperatures and other values derived from them in cars A and C, 1931–1 test, shipped from Plant City, Fla.*

Car and treatment	Average fruit temperature at completion of loading			Average drop in fruit temperature during test			Average drop in fruit temperature during precooling [1]			Ice-meltage equivalent of heat removed per ton of load	
	Top	Bottom	Entire load	Top	Bottom	Entire load	Top	Bottom	Entire load	During precooling	During whole test
	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	Lb.	Lb.
A, Precooled, not iced in transit	64.5	60.0	[2] 65.6	26.4	24.6	27.6	17.8	10.5	17.1	236	383
C, Standard refrigeration, not precooled	70.7	57.7	63.4	29.9	22.2	25.4	5.7	13.2	10.9	154	346
Difference [3]	−6.2	2.3	2.2	−3.5	2.4	2.2	12.1	−2.7	6.2	82	37

[1] For car C this means during the first 5 hours 40 minutes after loading was completed.
[2] Higher than average top temperature, car A, at completion of loading (table 17), but not inconsistent with it because the average load temperature is not the average of all top and bottom temperatures (p. 8).
[3] Minus sign (−) indicates excess of temperature, car C, over that of car A.

Table 14 shows that the average fruit temperature in the two cars when loading was completed was very nearly the same, but that during the precooling period of 5 hours 40 minutes, the fruit in the precooled car cooled decidedly faster than that in the car under standard refrigeration but not precooled. (Compare a temperature drop of 17.1° in the one car with 10.9° in the other.) The heat removed per ton of load during the whole test, expressed as ice-meltage equivalent, was 37 pounds greater in the precooled car than in the nonprecooled car; during the precooling period (about 6 hours) it was 82 pounds greater in the precooled car. For the whole test period, the average fruit temperature was about the same in both cars. At the end of the precooling period, however, it was 48.5° F. in the precooled car and 52.5° in the nonprecooled car. This quicker cooling in the precooled car is important in reducing decay, especially in the top layers of the load.

In table 14, the differences shown between the top and bottom layers are even more striking. (See also fig. 12.) For the test as a whole, the drop in fruit temperature was greater in the top layers of the cars. During the precooling period the average top-layer temperature in the precooled car dropped from 64.5° F. to 46.7° (17.8°) and in the nonprecooled or standard refrigeration car from 70.7° to 65.0° (only 5.7°), in spite of the fact that the higher initial tempera-

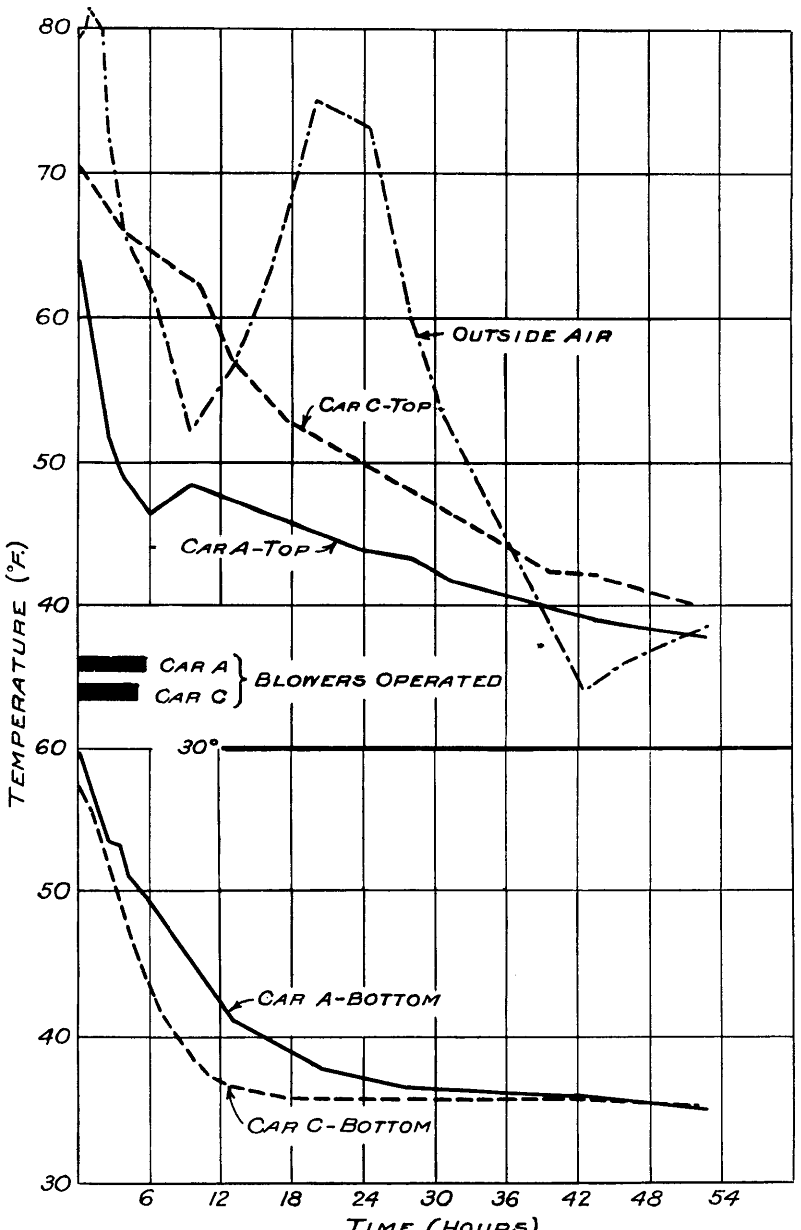

FIGURE 12.—Average top and bottom fruit temperatures in two test carloads of strawberries precooled by means of bunker blowers and shipped from Plant City, Fla., to New York, N. Y., March 14, 1931. Test 1931-1.

ture in the latter car was favorable to the removal of more heat during the precooling period.

It is important that this statement should not be misunderstood. If two loads having different starting temperatures are subjected to the same kind of precooling, at the same time, under the same outside conditions, the warmer load will lose heat more rapidly, at least for a while, because there is more heat to lose. It may not, and usually will not, reach as low a final temperature as the load that had the lower starting temperature, because in the meantime the cooler load has been cooling also and the early rapid rate of cooling in the warmer load is soon replaced by a much slower one. Equal precooling makes more of a show—in temperature drop—in the warmer load, but it does not result in as low final temperature as that established in the load that was cooler at the start. The differences between the two cars (A and C, table 14) show in a striking way the value of the kind of precooling used in this test, as a means of quickly bringing the warmest part of the load to a good carrying temperature.

The average bottom-layer temperature at the end of the precooling period was below 50° F. in both cars, but the average drop had been slightly greater in the nonprecooled car.

The practical significance of the results shown in table 14 can be summarized as follows:

In the precooled car, cooling was most rapid where it was most needed, namely, in the top layer, and was rapid enough in all parts of the car so that by the end of precooling the fruit had reached a temperature that will check the growth of *Rhizopus* and will exert some inhibiting effect even on gray mold.

In the nonprecooled car, cooling was most rapid in the bottom layer, which was already 13° cooler than the top layer when cooling began. The much slower cooling in this car (upper layer 5.7° in the first 5 hours 40 minutes, and 12.5° in the first 12 hours, from a starting temperature of 70.7°) would have allowed some development of decay in transit if the load had been in poor condition when placed in the car.

It will be shown (p. 30) that much better precooling was done in Florida in 1935 than that illustrated in table 16.

The relative efficiency of the bunker blowers, car E, as compared with the fan precooling apparatus, cars A to D and F to K, is shown by the data in table 15. Probably the most interesting comparison can be made between cars E and F, which were loaded the same day and precooled for the same length of time (fig. 13).

In car F, precooled with two 16-inch fans, the average drop in fruit temperature during precooling was 37.8° F. in the top layer and 22.7° in the bottom layer; the corresponding figures for car E, precooled with bunker blowers, were much lower, namely, 21.3° and 5.4°. The heat removed was equivalent to the melting of 313 pounds of ice per ton of load in car F, and of only 105 pounds in car E. At the end of precooling, the top-layer fruit in car F was 12° colder and the bottom-layer fruit 4.6° colder than fruit in the corresponding layers in car E, in spite of the fact that at the completion of loading the fruit in both top and bottom layers of car E was colder than the fruit in the same layers in car F.

Finally it should be noted that the poorer precooling by the bunker blowers took place in a car that received 200 pounds more salt than was supplied to car F where the fans were used.

A summary of the temperature conditions in nonprecooled cars and in cars precooled with fans or with bunker blowers is given in table 15.

TABLE 15.—*Summary of temperature conditions during precooling period in cars precooled by fans and by bunker blowers, and in nonprecooled cars*

Treatment	Average fruit temperature at end of precooling period		Average drop in fruit temperature during precooling period		Ice-meltage equivalent of heat removed per ton of load
	Top	Bottom	Top	Bottom	
	°F.	*°F.*	*°F.*	*°F.*	*Pounds*
Precooled with fans [1]	35.1	38.0	38.4	17.4	335
Precooled with bunker blowers [2]	46.8	45.7	20.1	8.6	214
Not precooled	[3] 63.0	[4] 41.6	[3] 5.8	[4] 11.1	[4] 140

[1] Figures are based on an average of 10 cars.
[2] Figures are based on an average of 13 cars.
[3] 9 cars averaged.
[4] 6 cars averaged.

It is evident from table 15 that precooling with bunker blowers is decidedly preferable to no precooling, but much less effective than precooling with the pressure-type fans. Additional evidence is furnished by the fact that in 15 cars precooled with bunker blowers in 1931 and 1932, the top layer took an average of 6¼ hours to reach 50° F., whereas in 10 cars precooled with fans in 1935, the top layer took on the average only about 3½ hours to reach 40°.

As further evidence of the excellent cooling produced by pressure-type fans it may be mentioned that two carloads of strawberries, thus precooled, and shipped from Plant City, Fla., to Los Angeles, Calif., in February 1935, arrived at destination with fruit temperatures satisfactory even though no ice had been added in transit.

A final illustration of the effects of precooling is given in figure 14, which shows smoothed curves calculated from the records of car C, test 1932–3 not precooled, car E, 1935, precooled with bunker blowers, and car F, 1935, precooled with pressure-type fans. The solid part of each curve represents the time during which the car was under observation; the dotted part is the course the curve would have taken if conditions affecting the load during any later time had been the same as they were during the period represented by the solid line. The broken horizontal lines are drawn at the temperatures that will give commercial control of rhizopus (45° F.) and gray mold (40°) during the usual transit time from southern strawberry sections to northern markets. All three cars are assumed to have had the same starting temperature.

Figure 14 shows that the top fruit in the car precooled with fans reached 45° in about 2½ hours and 40° in slightly less than 4 hours; in the car precooled with bunker blowers the top fruit was still about 47.5° at the end of precooling; in the nonprecooled car the top fruit did not reach even 45° during the whole transit period. The figure thus gives striking evidence that if temperatures that will control

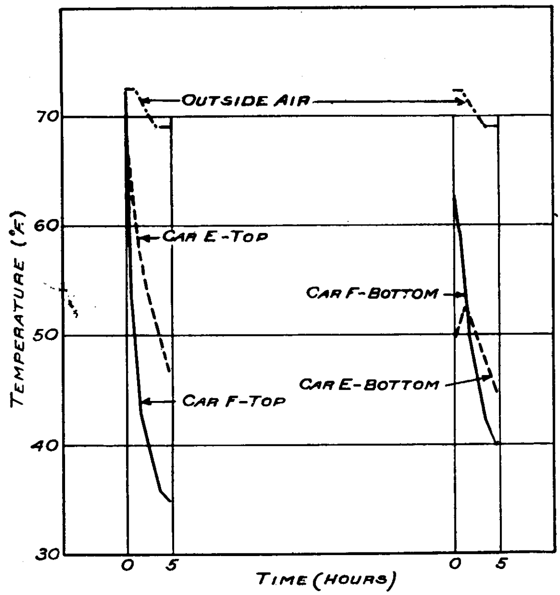

FIGURE 13.—Average top and bottom fruit temperatures in two test carloads of strawberries during precooling period in Plant City, Fla., March 18, 1935.

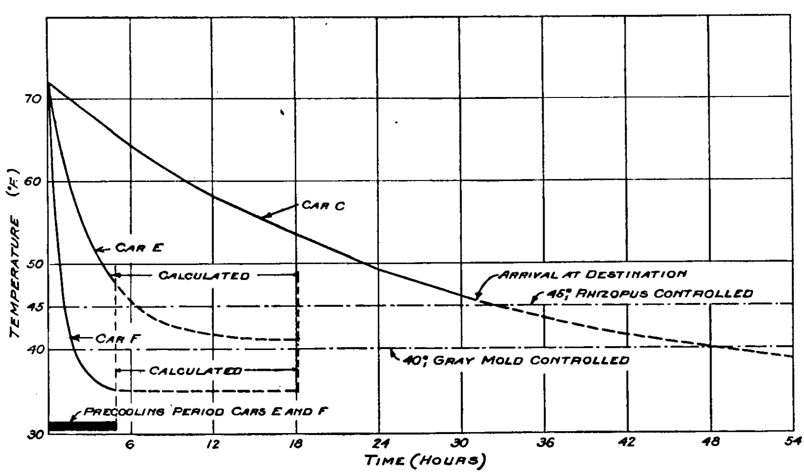

FIGURE 14.—"Smoothed" curves calculated from temperature records of top layers in three test carloads of strawberries, car C, test 1932-3, and cars E and F, 1935, shipped from Lawtey and Plant City, Fla., to northern markets. All curves drawn to show same starting temperature of fruit.

rhizopus and gray mold are to be established quickly in carloads of strawberries the cars must be precooled by some apparatus at least as efficient as the pressure-type fans.

EFFECT OF TWO SIZES OF FANS

Two sizes of pressure-type fans, 12-inch and 16-inch, were used in precooling 10 of the cars included in the 1935 tests. However, there are only three pairs of cars (A B, C D, and F G) in which the two sizes of fans were used, and which are fairly comparable in initial fruit temperature and length of precooling.

The summary of temperature conditions in these six cars as given in table 16 indicates that the 16-inch fans were somewhat more efficient than the 12-inch, even though four of the 12-inch fans were used in cars B and G, and only two of the 16-inch fans in any car.

TABLE 16.—*Summary of temperature conditions during precooling, in 6 precooled cars—3 precooled by 16-inch fans and 3 by 12-inch fans*

Size of fans	Average fruit temperature at end of precooling period		Average drop in fruit temperature during precooling period		Ice-meltage equivalent of heat removed per ton of load
	Top	Bottom	Top	Bottom	
	° F.	° F.	° F.	° F.	Pounds
16-inch	33.2	39.0	39.9	22.5	348
12-inch	35.9	37.5	35.8	14.9	297
Difference [1]	−2.7	1.5	4.1	7.6	51

[1] Minus sign (−) indicates excess in cars precooled by 12-inch fans.

In comparing the results obtained in precooling strawberries with bunker blowers and with pressure-type fans, there is one striking fact that should be brought out, namely, that at the end of precooling the top layer averaged colder than the bottom layer, when the precooling had been done with fans. On the other hand, in cars where bunker blowers were used the top layer averaged slightly warmer than the bottom. The figures are given in table 17.

TABLE 17.—*Average fruit temperature at end of precooling in 26 cars precooled by 2 different methods*

Location	Average fruit temperature when precooled by—		
	Bunker blowers (16 cars)	Pressure-type fans (10 cars)	Difference
	° F.	° F.	° F.
Top layer	46.8	35.1	11.7
Bottom layer	45.7	38.0	7.7
Difference [1]	1.1	−2.9	

[1] Minus sign (−) indicates excess in bottom layer.

Another fact brought out by these investigations is that in practically all precooled cars there is a rise in fruit and air temperature at one or more of the regular thermometer positions during the first 7 or 8 hours after precooling is stopped (fig. 15). The rise has been found chiefly in the top layer and is most marked in cars that have been precooled by means of the pressure-type fans. Details concerning its occurrence and magnitude in 22 precooled cars during the first 7 to 8 hours after precooling ended are given in table 18.

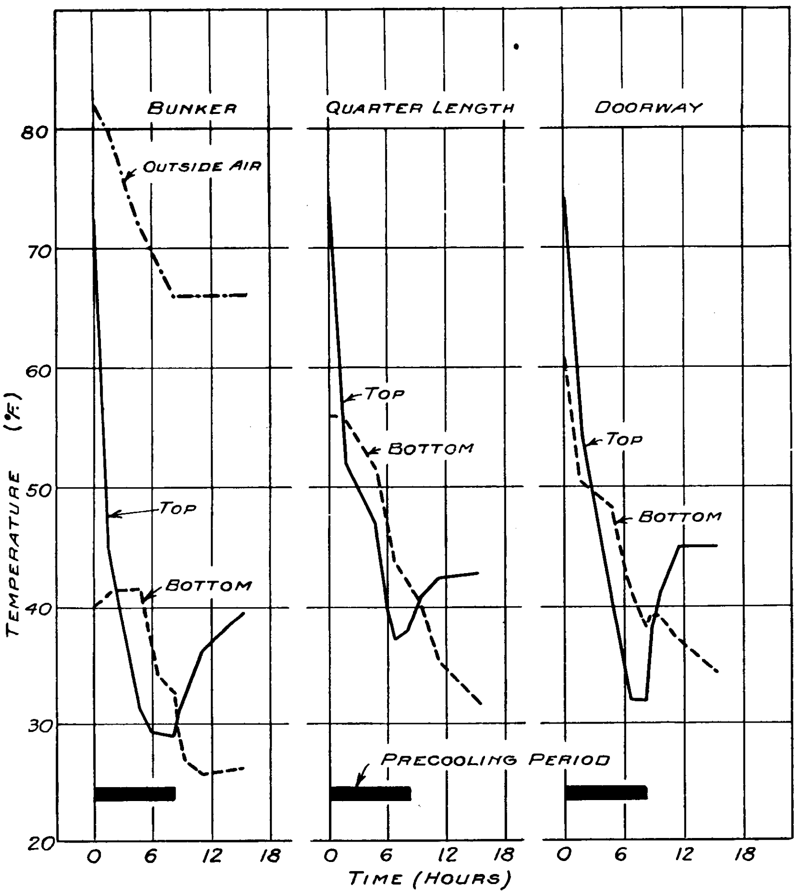

FIGURE 15.—Fruit temperatures at bunker, quarter-length, and doorway positions in a test carload of strawberries precooled and shipped from Plant City, Fla., March 18, 1935.

Changes in fruit temperature before and after precooling are shown in figure 15 for car H, 1935, precooled with fans for 8 hours 15 minutes.

This rise is caused presumably by the reestablishment of the slower, "normal" air circulation (p. 22 and fig. 10, *A*) that occurs in a loaded and iced refrigerator car in which no blowers or fans are being operated. It can be considered as an indication that the fruit at certain positions has been cooled to a temperature at which the car is unable to hold it.

TABLE 18.—*Changes in fruit temperature in 22 precooled cars during the first 7 to 8 hours after precooling ended*

Test no. or year	Number of precooled cars and type of apparatus	Temperature change	Temperature rise for positions where a rise occurred	
			Range	Average
			° F.	° F.
1931-1	2 (bunker blowers)	Dropped at all positions		
1931-2	1 (bunker blower)	do		
1932-1	4 (bunker blowers)	Rose at top bunker position in each car.	1.8 to 9.2	5.2
1932-2	3 (bunker blowers)	Rose at top bunker position in 2 cars and at top quarter length in 2 cars.	2.3 to 5.5	3.9
1932-3	2 (bunker blowers)	Rose at all 3 positions in 1 car	1.3 to 5.2	3.3
1932-4	4 (bunker blowers)	Rose at top bunker position in 3 cars and at top doorway in 1 car.	1.0 to 5.6	2.5
1935	1 (bunker blower)	Rose at top bunker position, fell at top quarter length and top doorway.	(1)	4.5
1935	5 (fans)	Rose at all positions in all cars except top quarter length in 1 car.	[2] 0 to 12.0	6.1

[1] Only 1 car, no range possible.
[2] Mostly 4.0 to 8.0.

The fact of the rise in temperature after precooling is no argument, however, against such precooling as was observed in the 1935 tests. For the transportation of strawberries the lower the temperature the better so long as frozen fruit does not result. The fact is discussed here chiefly to advise shippers that strawberries are not likely to remain as cold throughout the trip to northern markets as they are frequently found to be at the end of precooling by the better methods now in use.

EFFECT OF LENGTH OF PRECOOLING

At some points where precooling is practiced the loaded cars are picked up early in the afternoon for the trip northward. Under such conditions there is less time for precooling than at points where the pick-up train does not arrive or is not made up until late afternoon or evening. It may happen also that loaded cars are precooled for only an hour or two when actually there is time for a 4- or 5-hour precooling before they must leave.

The question naturally arises whether satisfactory precooling can be accomplished in an hour or two and, if not, how long precooling should last, under practical commercial conditions, to make it satisfactory; that is, to give real protection in transit against decay.

Data are presented (fig. 16 and table 19) showing the results obtained in cars A, B, C, test 1932–2, precooled for different lengths of time. The precooling of these cars was done by means of bunker blowers, four in each car.

TABLE 19.—*Fruit temperatures and other values derived from them in 3 carloads of strawberries precooled with bunker blowers, with initial icing only, 1932–2 test*

Car [1] and length of time precooled	Average fruit temperature at completion of loading			Average fruit temperature at end of precooling			Average drop in fruit temperature during precooling		
	Top	Bottom	Entire load	Top	Bottom	Entire load	Top	Bottom	Entire load
	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.
A, 5 hours 15 minutes	66.2	53.9	60.8	41.0	41.5	42.5	25.2	12.4	18.3
B, 3 hours 55 minutes	63.7	46.5	58.2	49.0	46.5	48.0	14.7	.0	10.2
C, 8 hours 3 minutes	61.2	49.5	58.8	39.0	42.0	39.0	22.2	7.5	19.8

[1] Car A received 400 pounds of salt during precooling; cars B and C, 600 pounds each.

TABLE 19.—*Fruit temperatures and other values derived from them in 3 carloads of strawberries precooled with bunker blowers, with initial icing only, 1932–2 test*—Continued

Car [1] and length of time precooled	Average drop in fruit temperature during test			Average fruit temperature at destination			Ice-meltage equivalent of heat removed per ton of load	
	Top	Bottom	Entire load	Top	Bottom	Entire load	During precooling	During test
	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	*Pounds*	*Pounds*
A, 5 hours 15 minutes	26.2	20.2	23.4	40.0	33.7	37.4	200	333
B, 3 hours 55 minutes	25.8	13.3	22.0	37.9	33.2	36.2	125	315
C, 8 hours 3 minutes	23.9	15.2	22.4	37.3	34.3	36.4	244	308

[1] Car A received 400 pounds of salt during precooling; cars B and C, 600 pounds each.

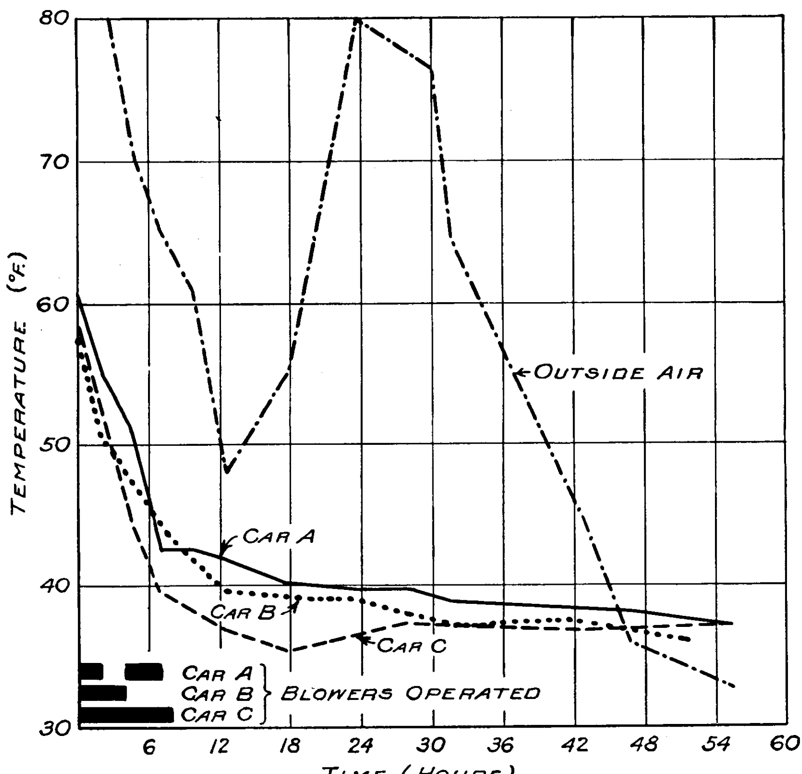

FIGURE 16.—Average temperatures for entire load in precooled test carloads of strawberries shipped from Plant City, Fla., to New York, N. Y. (car A), and Philadelphia, Pa. (car B), March 19, 1932. Test 1932–2.

The average drop in temperature of the load by the time of arrival at destination was nearly the same in the three cars covered by table 19. During precooling, however, the average drop was greatest (19.8°) in the car precooled the longest time (car C, 8 hours 3 minutes). The average drop in car A, precooled 5 hours 15 minutes, was 18.3°, and in car B, precooled 3 hours 55 minutes, 10.2°.

The ice-meltage equivalents of heat removed per ton of load are not significantly different in the three cars so far as the whole test is concerned. For the precooling period, however, the quantity of heat removed was roughly proportional to the length of the precooling; that is, the longer the blowers were run the more heat was removed.

The average amount of cooling of the top layer in these three cars was roughly proportional to the length of the precooling period; that is, the longer the precooling the greater the drop in fruit temperature. The relation is not so clear among the corresponding figures for the bottom layer; there was no drop at all in the car precooled for the shortest time, and the next largest drop (7.5° F.) was in the car precooled for the longest time. However, the average temperature of both layers at the end of precooling was below 50° in all the cars.

Results similar to those just discussed were obtained in other tests made in 1931 and 1932; all of them showed that, other things being equal, the longer the precooling period the lower the temperature reached by the fruit.

In the precooling work of 1935, in which more efficient apparatus was used, it was also found that as long as the fans were kept going the fruit and air temperatures continued to drop, but the striking differences due to this factor noted with the bunker blowers were not in evidence. With the fans used in cars F and H in the 1935 tests it was possible to speed up the precooling so effectively that the temperature was reduced satisfactorily in 4 hours and 50 minutes, and the additional cooling secured by operating the fans 8¼ hours was not great enough to justify the extra expense. Pertinent precooling data concerning these two cars are given in table 20.

TABLE 20.—*Average fruit temperatures in top and bottom layers, and other values derived from them, in 2 cars of strawberries precooled for different lengths of time by means of 16-inch fans, 1935 test, shipped from Plant City, Fla.*

Car and length of time precooled	Average fruit temperature at end of precooling		Average drop in fruit temperature during precooling		Ice-meltage equivalent of heat removed per ton of load
	Top	Bottom	Top	Bottom	
	° *F.*	° *F.*	° *F.*	° *F.*	*Pounds*
F, 4 hours 50 minutes	34.6	39.9	37.8	22.7	313
H, 8 hours 15 minutes	33.1	37.5	40.4	14.8	322
Difference [1]	1.5	2.4	−2.6	7.9	−9

[1] Minus sign (−) indicates an excess in car H.

EFFECT OF OUTSIDE TEMPERATURE

The outside temperature affects the rate of cooling of strawberries in cars in two ways: (1) Because it is an important factor in determining the temperature of the fruit at time of loading and (2) because it has a direct and continuing influence on the amount of heat leakage into the car during precooling and while the car is in transit.

EFFECT OF TEMPERATURE OF FRUIT WHEN LOADED

The importance of the temperature of the fruit at time of loading or when loading is completed has already been mentioned on pages 4 and 30. It was pointed out that of several cars handled under a given set of conditions, the one that has the highest temperature at the start would be expected to give up the most heat while in transit (p. 29). An illustration of this is furnished by cars A and B in test 1932-1. Both of these cars were precooled for about the same length of time, both received initial ice only, and neither received any salt in transit. The average temperature in car A at completion of loading was 57° F.; in car B, 61.6°. The ice-meltage equivalent of the heat

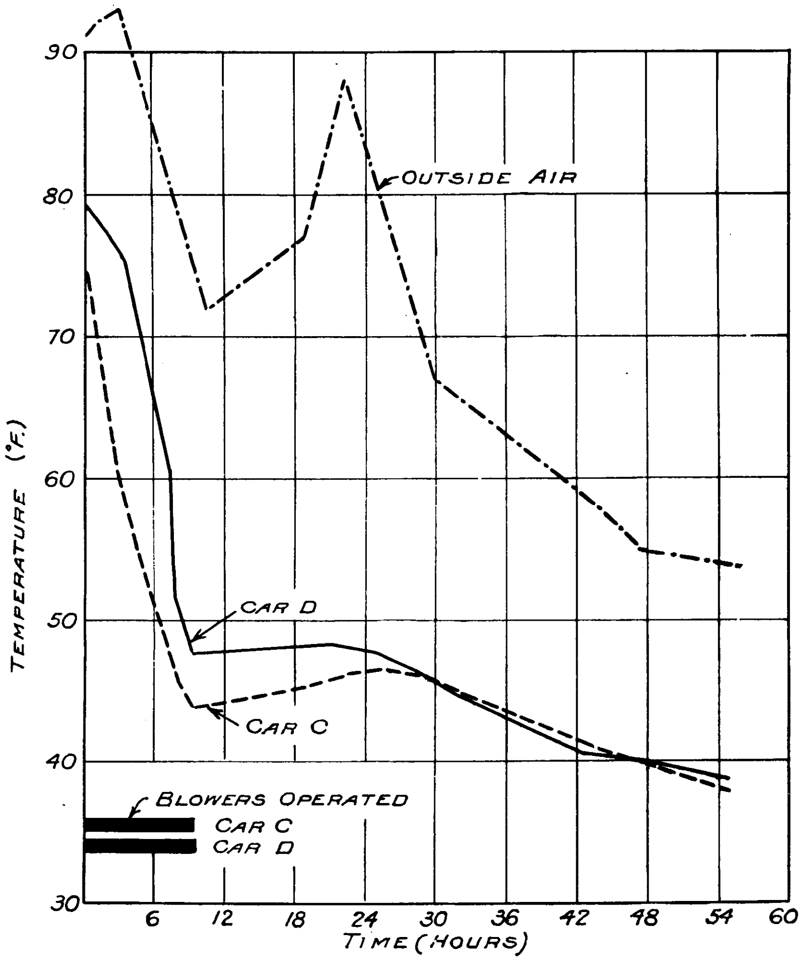

FIGURE 17.—Average fruit temperatures in top layers of two test carloads of strawberries shipped from Lawtey, Fla., to New York May 10, 1932, under standard refrigeration plus 4 percent of salt. Test 1932-4.

removed per ton of load from car A during the trip was 263 pounds, and from car B 347 pounds, or 84 pounds more per ton of load from the shipment having the higher loading temperature. A similar comparison could be made between cars B and C, test 1931-3, and between cars C and D, 1932-4. The average top-fruit temperatures in the latter two cars during the transit period are shown in figure 17.

However, it must be remembered that although one carload may lose heat more readily than another because of a higher loading temperature, it usually does not reach as low a temperature in transit as the other load, and therefore is not as well protected against decay. Early in the transit period heat can be removed more rapidly from the warmer load; but there is a larger quantity of heat to be removed from that load, and the result at the end of the trip is not as good as in the load that is cooler at the start. An example of this condition, so far as temperature is concerned, is furnished by cars A and B, test 1932–3. The pertinent data for these two cars are given in table 21.

TABLE 21.—*Temperature data for 2 test carloads of strawberries shipped from Lawtey, Fla., to New York, N. Y., May 4, 1932*

Car and length of time precooled	Average fruit temperature at completion of loading	Average fruit temperature at end of precooling	Average fruit temperature during test	Ice-meltage equivalent of heat removed per ton of load
	°F.	*°F.*	*°F.*	*Pounds*
A, 2 hours 25 minutes	63.5	54.5	44.7	348
B, 4 hours 10 minutes	57.6	48.5	40.7	286

The temperature drop during the whole test was 4.7° greater in car A than in car B (table 11), and more heat was removed from car A, yet the average temperature during the test was 4° lower in car B; the differences seem to be clearly the result of the higher loading temperature in car A.

The practical meaning of the comparisons just made is that every effort should be made to pick and load strawberries as early in the day as possible, before they have had time to become warm. If this is done there is less heat to be removed from them, which means less ice meltage, and there is a better chance that they will come to a good carrying temperature early in the transit period.

In 27 of the test cars discussed, the temperature of the fruit was taken by means of mercury thermometers just before it was placed in the car. This will be termed the loading temperature and should not be confused with the temperature at completion of loading. In fact, the latter is practically always the lower of the two, because the fruit begins to cool as soon as it is placed in the iced car.

An analysis of the records of 27 of the cars used in the 3-years' tests shows the following facts:

(1) In most of the cars only a small amount of cooling occurred in the top layer during loading. The range was from 0° to 12° F., and the average 2.8°.

(2) Cooling in the lower layer during the test was quite marked, ranging from 8.8° to 27.1° F. The average was 18.8°.

(3) While a car is being loaded, the doors should be kept closed whenever possible. In some localities, a canvas curtain in two pieces temporarily tacked in the doorway has proved beneficial in maintaining better temperatures during loading.

In discussing the effect of outside temperature, it is necessary to take account also of the effect of initial fruit temperature. A review of the pertinent data obtained during the 3-years' investigations shows that the higher the outside temperature and the average fruit temperature at time of loading, the longer the time required to bring the fruit to a good carrying temperature. Stated in another way, when the precooling periods were of about the same length, the precooling gave more desirable results when the outside temperature and the average top-fruit temperature were comparatively low than when they were high. The point can be further emphasized by noting that in precooling car B, 1932–2, in March it required 3½ hours to bring the top-fruit temperature to 50° F., whereas in May it required 21 hours to do the same work (cars A and B, 1932–4). In the 1935 tests, when the outside temperature averaged 74° and the top fruit 71° (car D), 6 hours' precooling cooled the top fruit to 32.6°; later in the month, when the outside temperature was 81° and the top-fruit temperature 78°, 7 hours' precooling brought the top fruit to 35.4°. Both represent excellent precooling, of course, but they also show the effect of high outside and high initial fruit temperatures.

The practical meaning of these facts is self-evident. Whenever possible, the outside temperature and the initial temperature of the fruit must be considered in determining how long a given carload should be precooled. Usually, however, a precooling period of only 2 or 3 hours should not be considered sufficient with the type of apparatus used in these tests. It will, of course, leave the load cooler than if no precooling had been done, but it is not really long enough under the weather conditions that are likely to prevail when strawberries are harvested. Results obtained in the precooled cars of these tests show that in January or February (in Florida) precooling with pressure-type fans should last for 5 to 6 hours and with bunker blowers for 6 to 7 hours, if fruit temperatures below 40° F. are to be reached by the end of precooling. For equally good fruit temperatures in April or May, precooling with pressure-type fans should last 6 to 7 hours and with bunker blowers 7 to 9 hours. If completion of loading and the arrival of the pick-up train come too near together for this, an effort should be made to lengthen the time. In some districts it may be possible to do this by having the loading of the cars completed earlier in the day; in others there may be a possibility of having train schedules changed.

Figures compiled by officials of the Railway Express Agency, Inc., show that during the strawberry-shipping season of 1934 in Florida the average time consumed in precooling was 4 hours per car in January, 5 hours in February, and 5 hours in March. The shortest time consumed in precooling was 2 hours and the longest time was 8 hours. This is about the range found during the investigations discussed in this bulletin.

It is estimated by Cooper and Park [8] of the Bureau of Agricultural Economics that in 1934 about 80 percent of the carloads handled by the auction companies at Louisiana loading points were precooled. These investigators also report that a review of inspection certificates, covering a sample of nearly 200 cars of Louisiana strawberries shipped during the 1934 season, showed that about one-sixth of the shipments were precooled less than 2 hours and only about one-fourth were precooled 4 hours or more. In other words, three-fourths of the cars covered by the review were not precooled long enough to give the desirable conditions shown to have existed in the best of the 27 pre-

[8] GALLOWAY, A. G. See footnote 6.

cooled test cars discussed in this bulletin. In 1935, of the 1,823 carloads of strawberries shipped from Louisiana, 1,518, or 83 percent, were precooled. The records of the Food Products Inspection Service of the Bureau of Agricultural Economics covering the precooled cars show that one-eighth of them were precooled for less than 2 hours and only about one-third for more than 4 hours. Top- and bottom-fruit temperatures at the end of precooling were above 40° F. in all but 12 cars, and these were precooled for various lengths of time ranging from 6½ to nearly 10 hours.

One further matter deserves consideration at this point. It is the general practice of operators of car-precooling apparatus to make a uniform flat charge for precooling each car. In view of the evidence presented above it would seem desirable if the practice were adopted of charging according to the length of precooling or the temperature reduction secured. Certainly, under a given set of conditions, a 4- or 6-hour precooling is worth more to the shipper than one that lasts only 2 hours.

EFFECT OF OTHER FACTORS

During these investigations no information was obtained that indicated how the efficiency of precooling is affected by the percentage of salt used during precooling or by the size of the load.

The mechanical condition of the car and its relation to the rate of cooling, as well as to the condition of the load in transit and on arrival at market, are controversial subjects which cannot be discussed adequately from data now available. If bunker screens are mashed against bunker walls, the circulation of air around the ice is impeded. Poorly fitting or worn doors or hatch plugs, or insufficient insulation, may permit increased heat leakage from the outside. The Department has no experimental results that show, in concrete figures, just how important such defects are under practical commercial conditions; however, evidence obtained during investigations made in various parts of the country on various kinds of fruits and vegetables indicate that cracks around doors or hatch plugs that will barely admit daylight have very little effect on the rate of cooling of the load as compared with the kind, amount, and condition of insulation in the car, and the icing of the car after loading.

EFFECT OF ALL FACTORS SUMMARIZED

The foregoing discussion on the efficiency of precooling can be summarized as follows:

The results of the strawberry-transportation tests indicate that the efficiency of precooling depends on (1) the temperature of the fruit at time of loading, (2) the outside temperature during precooling, (3) the length of the precooling period, and (4) the kind of apparatus used. Other factors undoubtedly of importance but not adequately investigated to date are (1) the percentage of salt used during precooling, (2) the size of the load, and (3) the mechanical condition of the car.

DESIRABLE FRUIT TEMPERATURE AT THE END OF PRECOOLING

The question is often asked, "What temperature should precooled strawberries have when leaving point of origin?" It is not easy, however, to give a brief, definite answer, because so much depends on the condition of the fruit at time of loading, the size of the load, the mechanical condition of the car, and the quantities of ice and salt to be furnished in transit. Consideration must also be given to the quantity of salt used in precooling since if any considerable excess of salt remains in the bunkers at the end of precooling it will continue to hasten ice meltage and may thus cause freezing in transit in the lower part of the load, especially near the bottom bulkhead opening.

Allowance must also be made for the effect of the outside temperatures through which the shipment is likely to pass. A fruit temperature at the start that would be safe for shipments moving out of Florida in late April or early May might be dangerously low for shipments moving from the same State in January or February, assuming, of course, that about the same amount of transit refrigeration is furnished in all cases.

Information concerning fruit temperatures at the top and bottom doorway positions at the end of precooling in 27 cars included in these tests is given in tables 22 and 23. Doorway temperatures are chosen because they are the most readily obtainable under commercial conditions. However, when so obtained, they should not be considered a reliable indication of the efficiency of precooling unless there is good reason to believe that they are as representative of temperatures throughout the load as the doorway temperatures recorded during these investigations.

TABLE 22.—*Fruit temperatures at doorway positions at completion of loading and at end of precooling in 16 test carloads of strawberries shipped from Florida to Philadelphia and New York, 1931 and 1932*

Test no. and car	Date loaded	Time precooled		Temperature at completion of loading		Temperature at end of precooling		Drop in temperature during precooling	
				Top	Bottom	Top	Bottom	Top	Bottom
		Hr.	*min.*	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*
1931-1:									
A	Mar. 14	5	40	67.7	61.6	52.5	50.7	15.2	10.9
B	do	4	55	70.5	59.4	54.0	49.5	16.5	9.9
1931-2: B	Mar. 24	4	30	64.6	55.5	53.5	44.8	11.1	10.7
1932-1:									
A	Feb. 26	5	57	70.1	53.6	56.0	47.5	14.1	6.1
B	do	6	20	59.9	56.6	50.3	44.5	9.6	12.1
C [1]	do	8	20	66.7	62.5	36.0	41.0	30.7	21.5
D	do	7	40	52.3	42.7	43.2	33.8	9.1	8.9
1932-2:									
A [1]	Mar. 19	5	15		60.0	55.0	46.0		14.0
B	do	3	55	62.0	57.3	50.5	50.0	11.5	7.3
C	do	8	3	69.1	67.0	44.1	46.2	25.0	20.8
1932-3:									
A	May 4	2	25	71.3	63.3	65.3	55.0	6.0	8.3
B	do	4	10		54.8	46.5	47.0		7.8
1932-4:									
A	May 9	4	18	74.8	81.7	57.2	54.0	17.6	27.7
B	do	4	3	75.2	68.0	62.3	56.4	12.9	11.6
C	May 10	9	20	73.2	77.0	44.3	44.4	28.9	32.6
D	do	9	30	83.1	76.5	48.1	46.5	35.0	30.0
Average				68.5	62.3	51.1	47.3	17.4	15.0

[1] Baffles used.

TABLE 23.—*Fruit temperatures at doorway positions at completion of loading and at end of precooling in 11 test carloads of strawberries shipped from Florida to northern markets, 1935*

Car	Date loaded	Time precooled		Temperature at completion of loading		Temperature at end of precooling		Drop in temperature during precooling	
				Top	Bottom	Top	Bottom	Top	Bottom
		Hr.	*min.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*
A	Mar. 11	5	50	75.7	64.0	34.0	33.5	41.7	30.5
B	do	6	15	74.0	70.5	42.5	41.5	31.5	29.0
C	Mar. 16	5	30	71.3	56.2	37.2	39.3	34.1	16.9
D	do	5	53	71.2	60.1	35.7	40.6	35.5	19.5
E	Mar. 18	[1] 4	50	73.1	66.7	54.2	46.7	18.9	20.0
F	do	4	50	70.0	71.1	33.0	37.6	37.0	33.5
G	do	5	0	71.9	64.2	35.0	34.7	36.9	29.5
H	do	8	15	74.3	61.1	32.8	38.1	41.5	23.0
I	Mar. 22	6	35	75.2	54.2	38.1	40.0	37.1	14.2
J	do	7	25	72.5	58.1	39.5	40.1	33.0	18.0
K	do	7	10	76.3	57.4	45.3	40.4	31.0	17.0
Average of 10 cars precooled with fans				73.2	61.7	37.3	38.6	35.9	23.2

[1] Car E precooled with bunker blowers; all others with fans.

It appears from table 22 that in the work of 1931 and 1932, the highest top temperature at the end of precooling, 65.3° F., occurred in the car that was precooled for the shortest time, namely, 2 hours 25 minutes. The lowest top temperature, 36°, was in a car where the precooling lasted for 8 hours 20 minutes and where canvas baffles were hung crosswise of the car at the doorway to direct the air downward that was coming from the blowers at the top of the bunkers.

In most instances the cars that were precooled the longest showed the greatest drop in doorway temperatures. The most noteworthy exceptions, car B, 1931–1, and car A, 1932–1, had higher temperatures at completion of loading (table 22) than other cars in the same tests (precooled for longer times) and so gave up more heat. It is important to note, however, that they did not reach as low a temperature at the end of precooling as did the other cars. The greatest drop in both top and bottom doorway temperatures occurred in car D, 1932–4, which was precooled for 9 hours 30 minutes.

The range of doorway temperatures at the end of precooling was from 36° to 65.3° F. at the top, and from 33.8° to 56.4° at the bottom. The average, although probably not very reliable because of the wide range, was 51.1° at the top and 47.3° at the bottom. If only those cars are considered that were precooled for 6 hours or more, the range was from 36° to 56° at the top and from 33.8° to 47.5° at the bottom. The average in such cars was top, 46°, and bottom, 43.4°.

It is shown in table 23 that in 1935, in 10 cars precooled with pressure-type fans, the range of doorway temperatures was from 32.8° F. to 54.2° at the top and from 33.5° to 46.7° at the bottom. The average was 37.3° at the top and 38.6° at the bottom.

The averages for the cars precooled in 1931 and 1932 are close to, or below, the temperature at which rhizopus rot, one of the most serious diseases of strawberries in transit, is definitely checked. They are not as satisfactory for the control of gray mold rot as the temperatures established in the cars used during the 1935 tests. It is therefore recommended as desirable, and as commercially practicable if some form of pressure-type fan is used in precooling, that strawberries when leaving point of origin should have a temperature close to, or slightly below, 40° F. at the top and bottom doorway. If this condition is established, the load as a whole should not warm up (p. 33) above a good carrying temperature during a transit period of 3 to 4 days, provided that the bunkers are re-iced to capacity after precooling is completed.

If less effective precooling equipment such as bunker blowers or similar apparatus, must be depended upon, the shipper should be prepared to continue precooling operations for a proportionately longer time to bring the doorway-fruit temperature to 40° F. or below in order to effectively check the rot fungi which are most destructive to strawberries in transit.

TRANSIT REFRIGERATION OF RAIL SHIPMENTS

Four different methods are used in the transit refrigeration of strawberries shipped by rail from Florida, namely, standard refrigeration, standard refrigeration plus salt, initial icing plus salt, and initial icing without salt (table 24). As previously mentioned, there is some less-than-carlot express movement of strawberries in open crates and in iced pony refrigerators, but the quantity of fruit handled in this way is comparatively small, much smaller than it was a few years ago.

TABLE 24.—*Icing and salting record, and other information relative to refrigeration of 25 test carloads of strawberries shipped from Florida to Philadelphia and New York, 1931 and 1932*

Test no. and car	Date loaded	Total ice supplied	Ice in bunkers at destination	Ice consumed	Ice consumed in loading and precooling	Ice consumed in transit	Time precooled	Refrigeration in transit	Manipulation of vents and plugs	Salt
1931-1:		*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Hr. min.*			
A	Mar. 14	20, 100	10, 925	9, 175	5, 600	3, 575	5 40	Initial icing only	Closed	400 pounds during precooling.
B	do	20, 296	13, 630	6, 666	4, 200	2, 466	4 55	Standard refrigeration	do	Do.
C	do	19, 480	13, 412	6, 068	2, 000	4, 068	(1)	do	do	300 pounds at completion of loading.
1931-2:										
A	Mar. 24	22, 262	12, 450	9, 812	3, 800	6, 012	(1)	do	Open to Ocala, Fla	3 percent during test.
B	do	24, 579	12, 713	11, 866	7, 000	4, 866	4 30	do	Closed	2.1 percent during precooling.
1931-3:										
A	Apr. 14	19, 563	13, 288	6, 275	0	6, 275	(1)	do	do	3 percent during test.
B	do	20, 962	14, 300	6, 662	0	6, 662	(1)	do	Open to Thalmann, Ga	Do.
C	do	20, 782	14, 300	6, 482	0	6, 482	(1)	do	do	Do.
1931-4:										
A	Apr. 21	21, 872	12, 782	9, 090	0	9, 090	(1)	do	Closed	Do.
B	do	23, 283	12, 854	10, 429	0	10, 429	(1)	do	Open to Jacksonville, Fla	Do.
C	do	21, 706	12, 854	8, 852	0	8, 852	(1)	do	do	Do.
1932-1:										
A	Feb. 26	15, 550	9, 410	6, 090	3, 600	2, 490	5 57	Initial ice only	Closed	600 pounds during precooling.
B	do	20, 900	10, 743	10, 157	6, 600	3, 557	6 20	do	do	Do.
C	do	22, 635	12, 901	9, 734	6, 400	3, 334	8 20	Standard refrigeration	do	Do.
D	do	20, 100	11, 665	8, 435	5, 800	2, 635	7 40	Initial ice only	do	Do.
1932-2:										
A	Mar. 19	20, 700	7, 863	12, 837	6, 400	6, 437	5 15	do	do	400 pounds during precooling.
B	do	18, 900	8, 953	9, 947	4, 600	5, 347	3 55	do	do	600 pounds during precooling.
C	do	21, 100	10, 744	10, 356	6, 800	3, 556	8 3	do	do	Do.
1932-3:										
A	May 4	21, 727	13, 454	8, 273	6, 527	1, 746	2 25	Standard refrigeration	do	2 percent during test.
B	do	22, 587	13, 721	8, 866	7, 387	1, 479	4 10	do	do	Do.
C	do	20, 484	13, 054	7, 430	4, 984	2, 446	(1)	do	Open to Jacksonville, Fla	3 percent during test.
1932-4:										
A	May 9	21, 700	12, 512	9, 188	5, 900	3, 288	4 18	do	Closed	2.3 percent during test.
B	do	21, 900	12, 250	11, 650	6, 400	5, 250	4 10	do	do	3.0 percent during test.
C	May 10	23, 900	11, 912	11, 988	8, 700	3, 288	9 20	do	do	4.0 percent during test.
D	do	25, 112	12, 876	12, 236	9, 612	2, 624	9 30	do	do	Do.

[1] Not precooled.

Cars for the handling of Florida strawberries are usually pre-iced the evening of the day previous to loading, and the doors are kept closed until the berries begin to arrive the next day for loading. In some instances the crates are stacked on the loading platform until enough are collected to warrant opening the doors and beginning the loading. In warm weather this is bound to be injurious to the fruit, especially if it has to stand in the sun. Furthermore, in many instances at least a third of the load, even though placed in the car, is exposed to the outside temperature until the final crates are loaded, the bracing set in place, and the doors closed for precooling. After the loading and precooling are completed, ice is added to replace that which has melted since the bunkers were filled. At strawberry-shipping points in Florida this is known as the "top-off" ice.

Nonprecooled cars are sometimes allowed to go as far as the first icing station with vents open and plugs out, for the purpose, as expressed by shippers, of cooling the load more quickly and allowing "harmful gases" to escape. The only gas that is likely to accumulate in unusual quantities in cars containing strawberries or other fresh fruits or vegetables is carbon dioxide. However, no evidence has been obtained by the United States Department of Agriculture that this gas ever reaches a high enough concentration in cars containing ordinary commercial shipments of strawberries to cause any damage to the fruit. Even in special tests with various concentrations of carbon dioxide (*3*), in pony refrigerators, and refrigerator cars, it was found that the flavor of strawberries remained normal where the carbon dioxide content of the air had fallen to 25 percent from 40 percent or higher at the beginning of the test by the end of 12 hours, and to 10 percent within 24 hours. The effect produced on strawberries by allowing cars to move part way to market with vents open and plugs out is discussed on pages 46, 47, and 48.

ICE AND SALT IN TRANSIT

Information concerning the quantities of ice and salt supplied to the 25 test cars used in 1931 and 1932 is given in table 24. In the 1935 tests the cars were not re-iced in transit and the total ice supplied is shown in table 12.

In considering the icing records of two or more cars, comparisons can be made between the quantities of ice consumed in transit, or during loading and precooling, or the total quantity supplied.

TOTAL ICE SUPPLIED

Comparing only the cars in any one test, and considering only the tests in which all cars moved under standard refrigeration, it is seen that the cars that were precooled received more ice during the test than those that were not precooled. An example is test 1931–2, in which car A, not precooled, received 22,262 pounds of ice and car B, precooled, received 24,579 pounds. A similar relation exists among the corresponding figures in tests 1931–1 and 1932–3. The differences seem chiefly due to the quantity of ice consumed during precooling.

One outstanding advantage of precooling has already been discussed, namely, that it brings about rapid cooling in the top or warmest part of the load soon after loading is completed. Another advantage of almost equal importance is that precooled cars can be shipped with only an initial icing—instead of under standard refrigeration—and still arrive at distant markets in good salable condition. An example of the effectiveness of such a method of handling shipments is seen in test 1932–1. The total ice supplied to car A of that test (precooled) was smaller than that supplied to any other of the 25 cars, yet the temperatures during precooling and in transit compare very favorably with those obtained in any of the other cars. It should be noted further that although the temperatures in this car in transit were very close to those in car D, of the same test, which moved under standard refrigeration, the latter car received about 3½ tons more ice during the whole test.

Precooling cars and sending them forward with only an initial icing not only saves expense for ice during the transit period, but it also saves time that would otherwise be needed for the re-icings en route that must be made under standard refrigeration. In sections where precooling is general it might be possible to adjust the loading hours or railroad schedules so that the extra time could be used at the shipping point for longer precooling of cars.

Since 1932, precooling and initial icing only have almost entirely supplanted standard refrigeration in the handling of carload lots of Florida strawberries, except for shipments moving in very warm weather late in the season. The change is chiefly due to results obtained in the transportation studies discussed in this bulletin.

ICE CONSUMED DURING LOADING AND PRECOOLING

Table 24, covering the tests of 1931 and 1932, shows that with the exception of car B, 1932–1, the longer the cars were precooled the greater the quantity of ice consumed. The irregularity in the case of car B seems to have been due to higher fruit temperatures in that car at completion of loading.

ICE CONSUMED IN TRANSIT

Comparing only cars in the same test, those which had been precooled consumed less ice in transit than those shipped without precooling. In view of what has been said in the preceding discussions concerning the effect of high or low loading temperatures, this result is precisely what should have been expected.

VENTILATION DURING EARLY PART OF TRANSIT PERIOD

As mentioned earlier, nonprecooled cars of strawberries are sometimes allowed to move to the first icing station with ventilators open and plugs out. The practice is much more common in Louisiana than in Florida. The effects produced in one test can be seen by considering the records of two cars (1931–3, cars A and B), given in table 25.

TABLE 25.—*Fruit temperatures in nonprecooled cars shipped from Florida under standard refrigeration plus 3 percent of salt, 1931–3 test*

Car	Average fruit temperature at completion of loading		Average fruit temperature when vents were closed		Average fruit temperature at end of test		Average drop in fruit temperature during time vents were open		Average drop in fruit temperature during test	
	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
A [1]	67.4	51.5	62.5	41.0	46.2	34.0	4.9	10.5	18.0	17.5
B [2]	68.1	53.1	62.0	36.5	41.8	32.8	6.1	16.6	26.3	20.3
Difference [3]	−.7	−1.6	.5	4.5	4.4	1.2	−1.2	−5.1	−8.3	−2.8

[1] Vents and plugs closed throughout test.
[2] Vents and plugs open from Lawtey, Fla., to Thalmann, Ga. (5 hours 20 minutes). Outside temperature while vents were open, 74° to 64° F.
[3] Minus sign (—) denotes excess in car B.

Fruit temperatures in the two cars were about the same at the time when loading was completed. When the vents were closed in car B, bottom-fruit temperatures were 4.5° lower in that car than in car A; top-fruit temperatures at that time were practically the same in both cars and too high for the control of decay. At the end of the test, both top and bottom temperatures were lower in the open-vent car, the differences being 4.4 and 1.2°. During the time when the vents were open, and for the test as a whole, the drop in temperature in both the top and bottom layers was greater in the open-vent car.

A comparison of the temperature conditions in a precooled car, vents closed, and a nonprecooled car in which the vents were kept open from Lawtey to Jacksonville, Fla., 2 hours 15 minutes, is given in table 26 and figure 18 (test 1932–3). (See also table 11.)

TABLE 26.—*Comparison of fruit temperatures in 2 cars, test 1932–3 shipped from Lawtey, Fla., to New York, N. Y., May 4, 1932*

Car	Average fruit temperature at completion of loading		Average fruit temperature at end of precooling period		Average fruit temperature at end of test		Average drop in fruit temperature during precooling period		Average drop in fruit temperature during test	
	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.
B, Precooled [1]	56.5	49.0	45.0	46.0	41.1	31.8	11.5	3.0	15.4	17.2
C, Nonprecooled [2]	70.5	55.6	65.7	42.0	45.5	32.2	4.8	13.6	25.0	23.4
Difference [3]	−14.0	−6.6	−20.7	4.0	−4.4	−.4	6.7	−10.6	−9.6	−6.2

[1] Vents closed. Standard refrigeration plus 2 percent of salt.
[2] Vents open 2 hours 15 minutes, outside temperature 81.5° to 75° F. Standard refrigeration plus 3 percent of salt.
[3] Minus sign (−) denotes excess in car C.

At completion of loading, the top fruit was 14° F. warmer in car C (not precooled) than in car B (precooled). This fact might be supposed to make comparisons impossible. It should be noted, however, that although the bottom fruit at completion of loading was 6.6° warmer in car C than in car B, the two series of bottom temperatures were never more than 2° apart (fig. 24) after about the first 9 hours, indicating that the marked differences between top temperatures in the two cars throughout the trip were due chiefly to the precooling of car B.

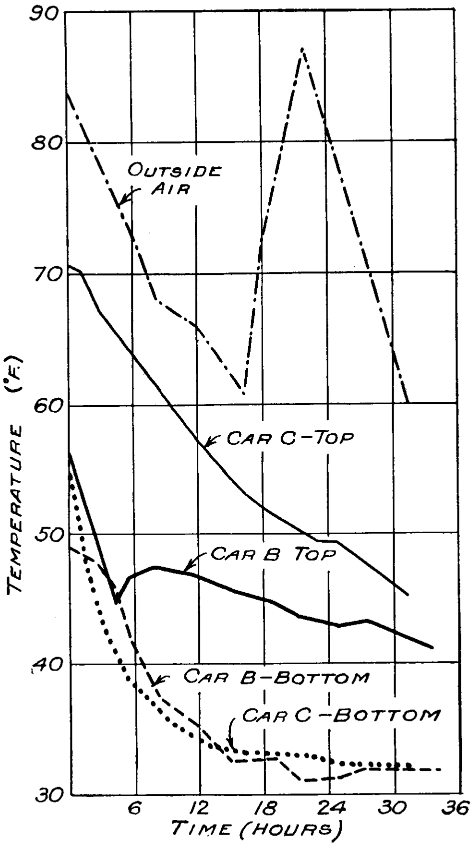

FIGURE 18.—Average fruit temperatures in top and bottom layers of two test carloads of strawberries shipped from Lawtey, Fla., to New York, N. Y., May 4, 1932. Test 1932-3.

At the end of the precooling period (4 hours 30 minutes) top temperatures were 20.7° F. higher in car C than in car B, and entirely too high for the satisfactory transportation of strawberries. At the same time, the average bottom temperatures were only 4° apart—46° in car B and 42° in car C. At destination the average top temperature was still 4.4° higher in car C than in car B; the average bottom temperatures were about the same in the two cars. The average top temperature during the test (table 11) was 55.4° in car C and 45.3° in car B. It is obvious that precooling for only about 4 hours gave better conditions for the transportation of strawberries from Florida than were furnished by heavy salting without precooling and the movement of the car with hatches open and plugs out to the first icing station.

The results of the two tests (car B, 1931–3 and car C, 1932–3) indicate that when strawberries are shipped without precooling, the cooling of the bottom layer can be hastened somewhat by keeping the vents open during the first few hours of the trip. It should be emphasized, however, that in both tests at the time when the vents were closed (table 11), top-fruit temperatures were not significantly lowered, being above 60° F., and therefore much too high for the control of strawberry decay, whereas in precooled cars, the fruit was brought below this temperature very soon after precooling began. Attention is also called to the fact that in all six cars of the two tests, 13 to 18 hours after the completion of loading was required for the fruit to reach 50°.

TEMPERATURE OF FRUIT ON ARRIVAL AT DESTINATION

It is believed by many shippers and receivers that the temperatures found in a carload of strawberries on arrival at destination are a reliable indication of the refrigeration the car has received.

That this is not altogether true is shown by a consideration of the data in table 11. In all of the 25 test cars of 1931 and 1932, whether precooled or not, the average fruit temperature at destination was below 40° F. and in 3 out of the 25 it was below 35°. The range was from 34.1° to 38.8°. The final top-fruit temperatures in these cars ranged from 37° to 46.2° and the final bottom-fruit temperatures from 28.2° to 36.2°.

All of these temperatures with tne exception of the lowest are within the range recommended in this bulletin as desirable for the transportation of strawberries. The important point is that in most instances they are the lowest temperatures reached by the several carloads, being several degrees below the average temperatures that prevailed in the loads during the trip to market, and they do not indicate the early establishment of desirable temperatures brought about by precooling.

This is shown in table 27, which summarizes the temperature conditions found in 16 precooled and 9 nonprecooled cars of the 1931 and 1932 tests at various intervals after completion of loading. The striking fact in this table is that in the precooled cars, the average top-fruit temperatures at the end of precooling (46.8° F.) was within 3.3° of the temperature reached in that layer at the end of 30 hours (43.5°). In the nonprecooled cars the top fruit at the time corresponding to the end of precooling period in the other cars averaged nearly 20° warmer than at the end of 30 hours. Both sets of cars reached about the same temperature 30 hours after loading was completed, but the precooled cars reached a desirable temperature very much sooner.

TABLE 27.—*Summary of average top- and bottom-fruit temperatures at various intervals after loading was completed, in 16 precooled and 9 nonprecooled test carloads of strawberries shipped from Florida, 1931 and 1932*

Location in car and treatment	At completion of loading	At end of precooling	12 hours after loading completed	18 hours after loading completed	24 hours after loading completed	30 hours after loading completed
Top layer:	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*
16 precooled	67.6	46.8	47.0	46.0	44.9	43.5
9 nonprecooled	68.5	63.0	54.3	49.6	47.3	43.7
Difference [1]	−.9	−16.2	−7.3	−3.6	−2.4	−.2
Bottom layer:						
16 precooled	54.6	45.7	37.2	33.5	32.8	33.0
9 nonprecooled	52.7	41.6	35.1	33.6	33.5	33.5
Difference [1]	1.9	4.1	2.1	−.1	−.7	−.5

[1] Minus sign (−) denotes excess in nonprecooled cars.

In the bottom layers, desirable temperatures were reached in all 25 cars by the end of the precooling period.

In 10 cars the top temperatures did not reach 50° F. until 15 hours or more after completion of loading. In one car (car C 1931–1, not precooled), although the top fruit had a temperature of 40.8° at destination, it did not cool to 50° until 24 hours after loading, and in this car (see test 1, below) 50 percent of the fruit showed rhizopus rot at destination. This condition was undoubtedly caused by the long delay in cooling the fruit to a temperature that will check the growth of the fungus (p. 5).

Temperatures were obtained at destination only in cars J and K of the 1935 series. They are very close to the averages found for the test cars of 1931 and 1932 (tables 12 and 13).

EFFECT OF TRANSIT TEMPERATURES ON DETERIORATION OF STRAWBERRIES

The preceding pages have been devoted chiefly to a discussion of different methods of refrigerating strawberries at loading point and in transit, and the effect on fruit temperatures when such methods were used. It is important to know, however, what the condition of the fruit was with respect to decay and other deterioration on arrival at market after being subjected to the various treatments. A brief statement will therefore be made concerning the conditions found when the loads and the various lots of test fruit were inspected at destination. For other information concerning the test fruit see page 13.

RESULTS IN 1931

TEST 1

No test fruit. Both precooled loads (cars A and B) arrived in good condition so far as decay was concerned. The load in the non-precooled car (car C) showed 50 percent of rhizopus rot at destination, but this was probably due largely to the fruit having stood on the loading platform in Florida from about 10 a. m. to 6 p. m., the time when the loading of this car was completed. During most of that period the fruit was exposed to the sun, in an outside temperature of 70° F. or higher. It can also be seen from figure 12 that the top fruit in this car did not reach 50° until 24 hours after completion of loading, thus allowing sufficient time for the decay to get started.

TEST 2

Part of the test fruit in these cars was packed and shipped wet and part dry. Inspection of the two lots on arrival at destination showed that whether the test lots were loaded wet or dry the percentage of sound fruit in those lots was about 10 percent higher in the precooled car (B) than in the car (A) that was not precooled. When car A (not precooled) was unloaded at Philadelphia, considerable frozen fruit (percentage not determined) was found in the bottom layer both at the doorway and at the bunkers. This condition doubtless resulted from a misunderstanding whereby 3 percent of salt by weight of the total capacity of the ice bunkers was added and then, in addition, 3 percent of the "top-off" ice. The total salt added was actually 3.8 percent of the bunker capacity in pounds of ice and was too much for the time of year (Mar. 24) at which this car was shipped, as shown by the freezing found at destination and the temperatures recorded en route.

TEST 3

As in test 2, part of the fruit in test 3 was packed and loaded wet, and part dry. On inspection at destination the percentage of sound, soft, and decayed berries in the test lots in each car was determined for both wet and dry lots. A comparison of these percentages (for the wet and dry lots combined) indicated that for the most part there was more difference among the lots at different positions in the same car than among the lots at the same position in different cars. This is the condition that should have been expected, in view of the relatively small differences in the average temperature of the three loads during the test (table 13).

TEST 4

None of the cars in this test was precooled; car A moved with vents closed during the whole trip and cars B and C moved with vents open to Jacksonville, Fla. All three moved under standard refrigeration. Inspection of the test fruit at destination showed so much irregularity from one position to another and from one car to another that any averages that might be calculated would be of doubtful significance. The treatment these cars received in transit seems to have made little if any difference in the condition of the fruit on arrival at destination.

RESULTS IN 1932

TEST 1

The condition of the fruit at destination in the 1932–1 test was for the most part satisfactory for commercial purposes and about the same in all four cars. Fruit at the top doorway position in car A (precooled 5 hours 57 minutes) was somewhat softer than that at the same position in car B (precooled 6 hours 20 minutes), and thus reflected the less-efficient refrigeration secured in car A.

TEST 2

When inspected at time of unloading, test fruit in car A of the 1932–2 test (precooled 5 hours 15 minutes) showed about the same average decay and bad decay as that in car C (precooled 8 hours 3 minutes). Berries showing slight decay averaged 34 percent of the total in the test crates in car A and 24 percent in car C. At loading time the strawberries in car B (precooled 3 hours 55 minutes) were slightly softer than those in car C but the appearance and color of the two loads were about the same. No test fruit was included in car B. Reference to precooling records shows that the fruit temperatures were adequately reduced in car A as well as in car C at the end of precooling so that under the conditions of this test 5¼ hours was just as beneficial as 8 hours in controlling decay.

TEST 3

The fruit from the three cars that made up this test was held at destination for 12 hours at about 70° F. and then inspected. The fruit from car B (precooled 4 hours 10 minutes) showed only half as much decay as that from car A (precooled 2 hours 25 minutes) and less than half of that found in the fruit from car C (not precooled). These figures are concrete evidence that 4 hours' precooling (car B) gave better results than either 2 hours' precooling (car A) or the movement of the car with open hatches and plugs out (car C) during the first part of the trip.

TEST 4

The fruit for the 1932–4 test from cars A, B, and C (all precooled) was held for 12 hours at destination at about 70° F. and then inspected. No test fruit was placed in car D. The figures for decay obtained in the inspection give no clear indication of how the condition of the fruit was affected by the different treatments which the cars received, because (1) the average decay in car C (heavy salting and long precooling) was slightly greater than in car A (moderate salting and shorter precooling); (2) the average decay in car B was almost 9 percent greater than that in car A although both cars were precooled for practically the same length of time and received about the same quantity of salt. The high percentage of decay in the test fruit from all three cars was probably due to the ripe and rather soft condition of this fruit when placed in the cars at Lawtey. It emphasizes not only the importance of loading only sound fruit, but also the difficulty of controlling decay in poor fruit even by the excellent transit refrigeration furnished in car C.

The irregularity in the occurrence of decay at different locations in the three cars was probably due to the fact previously mentioned (p. 17), namely, that carloads of strawberries usually consist of many small lots which vary greatly in quality and condition. Possible varietal differences do not have to be considered because only one variety, Missionary, is shipped from Florida.

During test 4 salt was added during precooling and in transit as follows: Car A, approximately 2.3 percent; car B, 3 percent; cars C and D, 4 percent.

The test was made from Lawtey, Fla., early in May 1932. At the time of unloading in New York, ice crystals were found in the fruit at the bottom of the load in car C as far as four stacks from the bunkers. No frozen fruit was found in any of the other cars in this test. The lower percentages of salt in cars A and B (2.3 and 3) are sufficient to explain the absence of frozen fruit in them.

TRANSPORTATION OF STRAWBERRIES BY TRUCK

In the eastern United States, the heaviest movement of strawberries to northern markets by motor truck is from North Carolina and producing districts northward from there. During the last 2 years, however, a substantial part of the Florida crop has been hauled to market in trucks, chiefly to cities in the South Atlantic States. The Bureau of Agricultural Economics estimates that during the season of 1933 the tonnage so handled amounted to a little more than 12 percent of the commercial Florida crop, and in 1934 to about 15 percent.

The trucks used for hauling strawberries to distant markets are generally large, and loads of 150 crates to almost a carload are not unusual. Loading is done at the shipping point (not in the fields) and at about the same time of day when the refrigerator cars are loaded. In most of the trucks the sides are slatted except at the front end, and there is a slatted rear-end gate. After the load is in place it is roped securely to prevent shifting. Heavy canvas tarpaulins are used when necessary to protect the loads from exposure to rain or the hot sun. The transit time to New York is about 36 hours from Wallace, N. C., and 8 hours from Dover, Del.

Several transportation tests with strawberries moving by truck have been made from shipping points on the Chesapeake Peninsula and North Carolina, but none from Florida. In view of the increasing use of the motor truck in the marketing of strawberries it seems desirable to include a brief discussion of the truck tests made.

In these tests the same kind of temperature apparatus was used as in the rail tests. The "bulbs" were inserted among the berries in quart or pint cups at various places in the load, usually at the top and bottom, front and rear, and at the top, middle, and bottom midway of the load from front to back. Readings were taken during the journey at times when the truck stopped for fuel or meals, and an inspection was made at destination to determine the condition of the fruit.

The temperature data obtained in a test from Wallace, N. C., in a load of one hundred and forty-four 32-quart crates of strawberries shipped by truck to Washington, D. C., April 29, 1929, are shown graphically in figure 19. No tarpaulin was used over the load.

Figure 19 shows that the fruit temperature responded quickly to changes in air temperature and that during most of the test the bottom of the load was slightly warmer than the top. There was very little difference in temperature between the front and the rear parts of the load. The lowest average temperature en route—42.5° F. at 4:35 a. m., about 4 hours after the time of minimum outside temperature—was 23.5° below the loading temperature of 66°. From 4:35 a. m. onward, the fruit temperature rose as the outside air grew warmer, and at the end of the trip it was only 7.6° below the loading temperature.

During most of the trip the fruit temperatures were below the temperature of the outside air. This is just the reverse of the condition usually found in loaded, iced refrigerator cars and probably is caused by evaporation from the fruit surface due to rapid air circulation while the truck is in motion and the normal lag in fruit temperatures behind air temperatures. Nothing is known of the relation that might exist between fruit and air temperatures in truck shipments of strawberries moving in hotter weather. In truck tests with peaches in June, July, and August, it was found that the fruit in the outer parts of the load was usually cooler than the outside air, whereas that in the interior of the load or at the bottom was usually warmer. This suggests that a similar condition might exist in loads of strawberries if they were moved by truck at that time of year.

Inspection at Washington showed the strawberries in this test from North Carolina to be in good condition except for slight bruising in the cups next to the lids of the crates.

Similar results were obtained in truck tests from other shipping points (fig. 20).

From the close relation shown between fruit temperatures and the temperature of the outside air, it is evident that the departure of the trucks should be so timed that as much as possible of the trip will be made at night. On long hauls the load should be kept covered with a tarpaulin during the hottest part of the day, but not so tightly as to prevent good circulation around and through the load. Care should also be taken to stack the crates so as to facilitate air circulation as much as possible.

MISCELLANEOUS OBSERVATIONS

During these investigations various matters have been considered which, although of importance to shippers, carriers, and receivers,

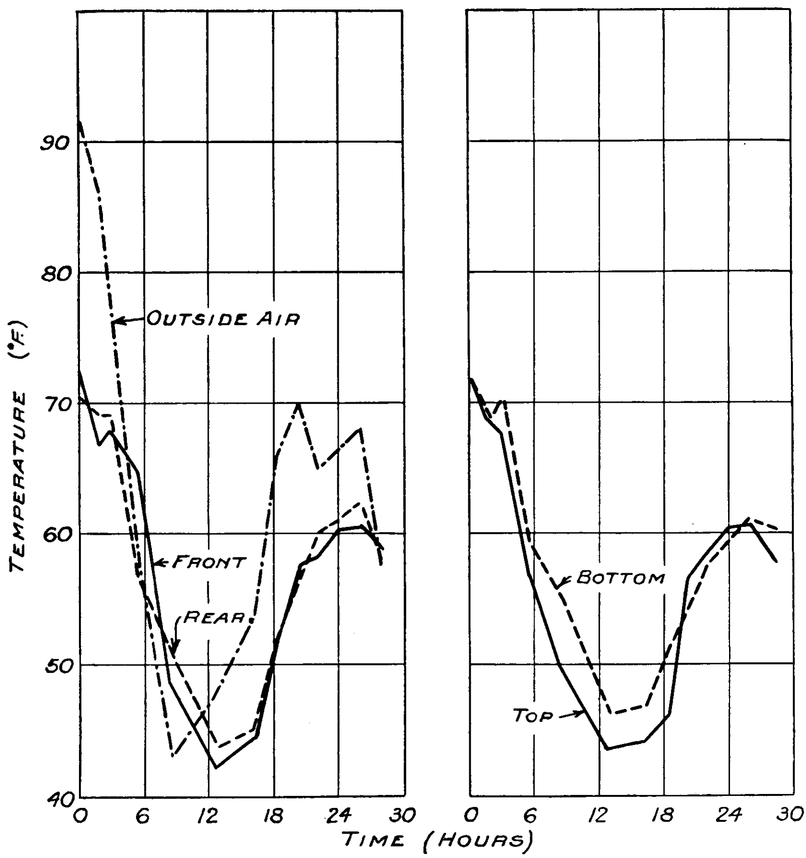

FIGURE 19.—Average temperature of fruit during a transportation test with strawberries moving by motor truck from Wallace, N. C., to Washington, D. C., April 29, 1929. Truck left Wallace about 4 p. m.

could not conveniently be discussed under any of the headings thus far given. These will now be treated briefly.

(1) The results of the carload tests give no clear indication as to the best height of load in comparable cars, or whether the height of the load can safely be increased if the load is precooled before it leaves the shipping point.

(2) In test 1932–1 a standard wooden car (the only one used in those investigations) was used for comparison with three all-steel cars.

At the beginning of precooling, the fruit temperature in the bottom layer at the bunker and the quarter-length positions averaged 46.5° F. in car B (all-steel, precooled 6 hours 20 minutes) and 58.0° in car A (wooden, precooled 5 hours 57 minutes). In the top layer the average fruit temperature when precooling began was about the same in both cars.

During precooling, fruit temperatures at the top bunker position dropped more rapidly in the all-steel car (car B) than in the wooden car (car A). It was noticeable, however, that in both top and bottom layers at the doorway and the quarter-length positions the fruit temperatures in car A were in most cases lower than those in car B up to about 24 hours after the first reading was made; after that time the temperatures were generally somewhat higher in car A than in car B. Toward the end of the trip, fruit temperatures in both top and bottom layers dropped faster in car B than in car A. The air temperature at the bottom bunker position dropped lower in car A

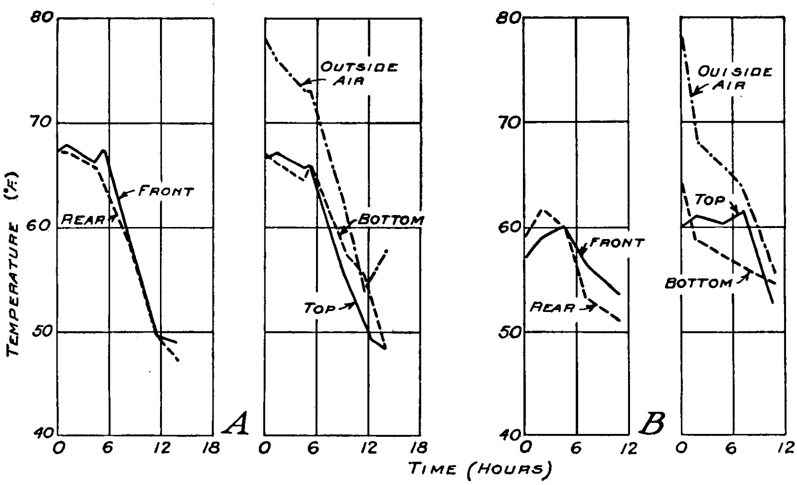

FIGURE 20.—Average temperatures of fruit during two transportation tests with strawberries moving by motor truck from (*A*) Tin City, N. C., to Washington, D. C., April 26, 1929, and (*B*) Salisbury, Md., to New York, N. Y., May 17, 1929. Truck left Tin City about 12:30 p. m. and Salisbury about 1:30 p. m

(19.8° F.) than that in car B (23.8°), due possibly to the relatively larger quantity of salt in the bunkers of car A. (The bunker capacity of car A was 11,900 pounds of ice and of car B 14,300.)

The difference in temperature between these two cars and the generally more desirable conditions in car B are believed to have been due to three factors: (1) The greater inside dimensions of car B which permitted better spacing of the crates, (2) the greater ice capacity of the bunkers of car B, and (3) the thicker insulation in car B (table 8).

(3) Strawberries will cool faster in pint cups than in quart cups, because in the former there is more fruit surface exposed to the circulating air.

(4) Under similar conditions in the car, fruit packed wet should cool faster than fruit packed dry, because evaporation of moisture from the fruit by the moving air removes heat. Experimental results bearing on this point are given on page 8.

(5) There is no advantage in adding salt to the ice in the bunkers very long before cars are loaded. Such a practice melts the ice rapidly, but the extra cooling so produced may be lost before the cars are loaded.

(6) When cars are not precooled there seems to be some advantage, so far as the bottom layer is concerned, in keeping the vents open for the first 2 or 3 hours of the transit period. If cars are precooled, the vents should be kept closed throughout the transit period.

SUMMARY AND RECOMMENDATIONS

In the handling, transportation, and precooling investigations discussed in this bulletin, 36 test carloads of Florida strawberries were used, of which 27 were precooled, 16 with bunker blowers and 10 with pressure-type fans, and 1 with a motor truck apparatus. Both the bunker blowers and the particular truck apparatus used are now practically obsolete.

The investigations were conducted in March and April 1931, February, March, and May 1932, and March 1935.

The results obtained serve as a basis for the following recommendations:

If fruit is warm when loaded (75° F. or above), as much as 5 percent of salt can safely be used during precooling, provided the precooling period is long enough so that most of the salt will be used up before the car is "pulled."

In warm weather, if cars are not precooled and move under standard refrigeration, 4 percent of salt can safely be used at time of loading, but at the transit re-icings should not exceed 3 percent.

In cool weather, when outside temperatures in transit are likely to go below 32° F., 3 percent of salt is as much as can safely be used during precooling. If precooling brings the bottom doorway temperature within the range, 40° to 45° F., initial icing only will be sufficient for shipments that are likely to pass through freezing temperatures.

In icing cars for precooling special care should be taken. The ice should not be chopped finer than about 50-pound pieces until within approximately a foot of the hatch bottom. At this point the surface should be piked down level, and fine enough to hold the salt which should then be added. The part of the bunker above the salt should be filled with ice cut into 25-pound pieces. In the hatchways the ice should be cut into smaller pieces and forced under the bridge and around the sides and ends of the bunker. This fills the voids in the upper section and prevents short circuiting of the air over the top.

This method of icing the bunkers provides air channels through the ice and facilitates refrigeration by permitting more air to be drawn through the ice mass increasing its contact with cooling surfaces instead of merely moving it over the outside of the bunker screen and cooling largely by contact with the outside of the ice mass. As precooling proceeds, large spaces may be melted out of the ice mass so that before re-icing the ice remaining should be thoroughly piked down. Where rapid cooling is desired the ice supplied should be in large enough chunks so that it will not close air channels, but after cooling has been accomplished the ice can be chopped finer so as to get more into the bunkers and make it last longer, an important consideration in precooled loads which are to move under initial icing only.

If 600 pounds of salt are used during precooling, in the type of cars discussed in this bulletin, it probably will be most effective if added in two different lots, 400 pounds at the beginning and 200 about the middle of the precooling period; if only 400 pounds are used it should all be put in the bunkers at the start of precooling.

It is recommended that strawberries when leaving point of origin should have a temperature of 40° F. or slightly lower at the top and bottom doorway.

LITERATURE CITED

(1) Brooks, C., and Cooley, J. S.
1917. Temperature relations of apple-rot fungi. Jour. Agr. Research 8: 139–164, illus.

(2) ——— and Cooley, J. S.
1921. Temperature relations of stone fruit fungi. Jour. Agr. Research 22: 451–465, illus.

(3) ——— Miller, E. V., Bratley, C. O., Cooley, J. S., Mook, P. V., and Johnson, H. B.
1932. Effect of solid and gaseous carbon dioxide upon transit diseases of certain fruits and vegetables. U. S. Dept. Agr. Tech. Bull. 318, 60 pp., illus.

(4) Haller, M. H., Harding, P. L., Lutz, J. M., and Rose, D. H.
1932. The respiration of some fruits in relation to temperature. Amer. Soc. Hort. Sci. Proc. (1931) 28: 583–589.

(5) ——— Harding, P. L., and Rose, D. H.
1933. The interrelation of firmness, dry weight, and respiration in strawberries. Amer. Soc. Hort. Sci. Proc. (1932) 29: 330–334, illus.

(6) Link, G. K. K., Ramsey, G. B., and Bailey, A. A.
1924. Botrytis rot of the globe artichoke. Jour. Agr. Research 29: 85–92, illus.

(7) Magness, J. R., and Taylor, G. F.
1925. An improved type of pressure tester for the determination of fruit maturity. U. S. Dept. Agr. Circ. 350, 8 pp., illus.

(8) Mann, C. W., and Cooper, W. C.
1935. The refrigeration of oranges in transit from California. U. S. Dept. Agr. Tech. Bull. 505, 88 pp., illus.

(9) Rose, D. H.
1924. Leather rot of strawberries. Jour. Agr. Research 28: 357–376, illus.

(10) ———
1926. Diseases of strawberries on the market. U. S. Dept. Agr. Circ. 402, 8 pp., illus.

(11) ——— Haller, M. H., and Harding, P. L.
1935. Relation of temperature of fruit to firmness in strawberries. Amer. Soc. Hort. Sci. Proc. (1934) 32: 429–430, illus.

(12) Stevens, N. E.
1925. Strawberry diseases. U. S. Dept. Agr. Farmers' Bull. 1458, 10 pp., illus. (Revised, 1933.)

(13) ———
1932. Market diseases of strawberries from the southeastern states, 1926 to 1930. U. S. Dept. Agr. Circ. 219, 4 pp.

(14) ——— and Wilcox, R. B.
1917. Rhizopus rot of strawberries in transit. U. S. Dept. Agr. Bull. 531, 22 pp., illus.

(15) ——— and Wilcox, R. B.
1918. Further studies of the rots of strawberry fruits. U. S. Dept. Agr. Bull. 686, 14 pp.

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